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APR 80 L E BAKER, R L DE HOFF, W E HALL
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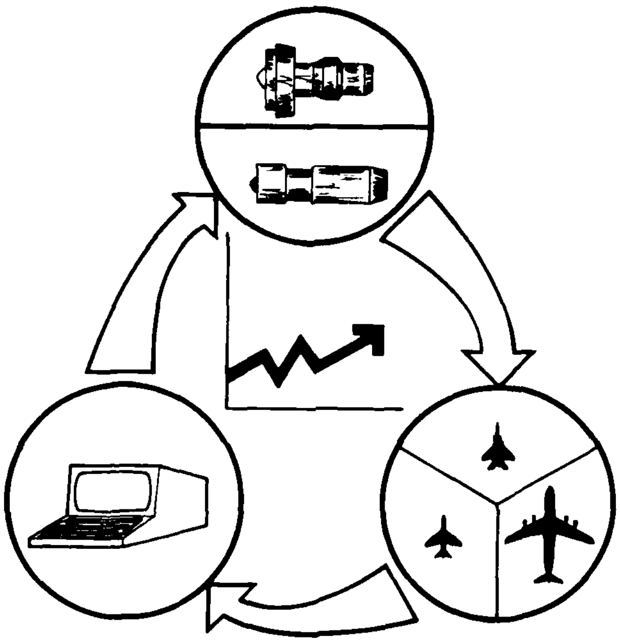
AFWAL-TR-80-2053 VOLUME II

TURBINE ENGINE FAULT DETECTION AND ISOLATION PROGRAM

PHASE I — Requirements Definition Study for an Integrated Engine Monitoring System



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SEPTEMBER 1980

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FINAL REPORT FOR PERIOD 15 NOVEMBER 1978 — 15 AUGUST 1979

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Automated engine monitoring has emerged as an important element in the Air Force's strategy to reduce propulsion system support costs and to improve aircraft operational availability. There has been a long history of development activity directed towards engine monitoring. These systems have demonstrated that sensor and automated data acquisition can be implemented effectively in both prototype and operational applications. Historically, however, no Air Force system has resulted in validated improvement in the engine maintenance and logistics process nor in a substantial cost savings.

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20. ABSTRACT (Continued)

This situation is due in part to the fact that the performance data were not reduced to a concise, usable format relevant to the decision process of the maintenance personnel. Moreover, there was no procedure developed for integrating the performance data into the maintenance framework.

This report presents the results of an intensive study of the Air Force maintenance/logistics process based on a selected sample of tactical bases, depots, and major commands. The objective is to define the requirements that the Air Force engine management structure imposes on automated data integration, in general, and engine performance monitoring, in particular. Such an automated integration of turbine engine monitoring system data with current data systems requires coordination between a variety of sources, both manual and automated. The results of this study are the requirements for such integration based on typical Air Force maintenance needs.

PREFACE

The work described in this report was performed under Contract No. F33615-78-C-2062 for the Aero Propulsion Laboratory of the Air Force Wright Aeronautical Laboratories (AFWAL/POTC), Wright-Patterson Air Force Base, Ohio. The technical monitor for AFWAL/POTC is Mr. Charles A. Skira. Principal authors from Systems Control, Inc. (Vt) are Ms. Laura Baker, Dr. Ronald L. DeHoff and Dr. W. Earl Hall, Jr. Computer programming support was provided by Mr. W. Lee Moore. Report preparation efforts were directed by Ms. Clare Walker.

Several Air Force operational units and organizations actively participated in this study effort. Their technical input to the Turbine Engine Fault Detection and Isolation Program is acknowledged. These include HQ Air Force Logistics Command/LOP, Wright-Patterson Air Force Base; HQ Tactical Air Command/LGMS, Langley Air Force Base; San Antonio Air Logistics Center/MMP, Kelly Air Force Base, Oklahoma; Air Logistics Center/MMP, Tinker Air Force Base; 1st Tactical Fighter Wing, Langley Air Force Base; 354 Tactical Fighter Wing, Myrtle Beach Air Force Base. Participation by the Air Force Operational organizations was coordinated by Captain William Rutley, AFLC/LOP.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES
APPENDIX B

LIST OF FIGURES (Continued)

APPENDIX B

LIST OF FIGURES (Continued)

APPENDIX C

LIST OF FIGURES (Continued)

APPENDIX C

APPENDIX D

LIST OF FIGURES (Continued)
APPENDIX D

LIST OF TABLES

APPENDIX A

APPENDIX B

LIST OF TABLES

APPENDIX C

APPENDIX D

APPENDIX A
ORIENTATION INTERVIEW ANALYSIS

I. PURPOSE OF INTERVIEWS

Orientation interviews were undertaken during the Phase I activity to accomplish the following objectives:

(a) identify key personnel with valid engine maintenance management background, experience and responsibility;

(b) formulate relevant and valid operating scenarios for the survey;

(c) familiarize management at targeted base, ALC, HQAFLC, and MAJCOM centers within the TEFDI program.

Members of the program team interviewed key Air Force personnel at the target organizations listed in Table 1. Personnel selection at each site was limited by scheduling requirements. A reasonable cross section of viewpoints was solicited and the response at each site was excellent. In the following summaries, the opinions of the interviewees are presented.

1.1 BASE ORIENTATION MEETINGS

Base orientation meetings were held at 1 TFW, Langley AFB and 354TFW, Myrtle Beach AFB. The objectives of the meetings were as follows:

(1) Types of maintenance decisions that are being made at the base level.

(2) Frequency and priority of base level engine maintenance procedures.

(3) Information currently utilized at the base level to make engine maintenance decisions.

(4) Format and accessibility of engine management information.

Table 1 Organizations Targeted for Orientation Interviews

ORGANIZATION	LOCATION	ACTIVITY
1 TFW	Langley AFB	F15 Base
354 TFW	Myrtle Beach AFB	A10 Base
San Antonio ALC	Kelly AFB	Engine Depot
Oklahoma City ALC	Tinker AFB	Data Service Center
HQTAC	Langley AFB	Major Command
HQAFLC	Wright Patterson AFB	Headquarters

1.2 MAJOR COMMAND ORIENTATION MEETINGS

Orientation meetings were held at TAC headquarters, Langley AFB and with personnel experienced with SAC/MAC/ADC procedures who are currently assigned to HQAFLC, WPAFB.

Objectives for Meeting with HQTAC Personnel

The following items will be explored with cognizant personnel:

(1) Impact of TAC's mission on maintenance and engine management procedures.

(2) On-going condition monitoring programs.

(3) Experiences with on-condition maintenance and engine monitoring.

(4) Operational obstacles to the implementation of automated turbine engine monitoring at the base level.

(5) Performance factors that are tracked at the TAC command level (e.g., sortie rate, NRTS, maintenance man hours per operating hour, etc.).

(6) Information currently available for formulating and tracking these performance factors.

(7) Format and accessibility of engine management information.

Objectives for Meetings with SAC/MAC/ADC Personnel:

(1) Impact of the respective command's mission on maintenance and engine management procedures and policy.

(2) On-going condition monitoring programs.

(3) Automated turbine engine monitoring and its impact on base level operations.

(4) Operational obstacles to the implementation of automated turbine engine monitoring.

(5) Information currently utilized to make engine maintenance decisions.

(6) Format and accessibility of engine management information.

(7) Experience with MMICS.

II. INTERVIEW RESULTS

Both discussion sessions and personal interviews were completed at each target organization. The following sections document these results.

2.1 BASE LEVEL

2.1.1 Discussion Analysis

Based on information obtained during base level orientation discussions, certain key issues for automated engine monitoring and maintenance/logistics management have been identified. These issues will impact the system requirements generated in Phase I.

(1) Base Level Operations -- The requirements of the users at the base level will drive the system requirements for turbine engine monitoring. This applies particularly to the format of data, hardware capability and the update frequency. The base appears to be the best place to manage the individual engines. The ability for base personnel to diagnose and isolate engine faults is a critical requirement for the generic TEMS. In order to exploit the modular engines, e.g., the F100, this isolation must be to the module level. Last year, 120 assembled F100's were transported to SAALC for maintenance. A significant portion of these returns could be attributed to the bases' inability to isolate the engine fault.

Currently, the only information used to manage engines are LCF counts, operating hours, and diagnostic signatures. This information needs to be cross-referenced to engine serial number, aircraft tail number, base location and Julian date. Multiple signature spreads, trends, and other information (e.g., GPA, SOAP, vibration history) would be available to users on an exception basis. It will be important to determine which base level personnel need to interrogate the system and determine which portions of the data base they can access.

It is anticipated that the major impact of automated engine monitoring will be felt at the base level. The system requirements should address the constraints of the base operating environment (e.g., limited manpower, level of skill, man-machine interface, etc.).

(2) MMICS Experience -- The Air Force experience developing and implementing the base level MMICS processor underscore the criticality of integrating base level hardware/software requirements. The information capabilities of MMICS impact interface requirements for automated monitoring.

2.1.2 Personal Interviews

2.1.2.1 Data Processing Specialist

(1) Profile: This USAF Major has extensive experience in maintenance policy/procedure development regarding data processing requirements dating from C4016 system. At TAC, he developed engine tracking procedures unique to the command and was involved with base level processing until MMICS came on board. He has been in automated systems management for hardware, weapon system, MAJCOM, and field level applications.

(2) Data System Requirements and Observations:

(a) MMICS interface with OCALC data bank creates problems with compatibility, especially of data edits at two locations. Base level system keeps time change item responsibility, tracked components, configuration management and life consumed.

(b) Time change tracking system at Langley requires 685000 disc segments for MMICS. Updates come towards from flightline via EHR inputs, and manual cycles. Every transaction is transferred to OCALC daily via AUTODIN. Base records encompass approximately the last 90 days of data.

(c) Information required at base involves time change forecasts and all parts linked to next higher assembly for ease in location.

(d) Base experience and success with MMICS ranges from excellent to very poor, depending on local base management support.

2.1.2.2 HQTAC Base Engine Troubleshooter

(1) Profile: This SMSgt has extensive experience in engine maintenance starting in 1961. He was a field instructor for nine years on the J79, J56, J33, J57, TF41, TF30. He has had extensive F111 (TF30) experience in fighter wing, test cell, trim pad and JEIM activity. Recently has had been working F100 problems extensively.

(2) Observations on maintenance information requirements:

(a) The F100 is basically a "good engine" with support ability problems. They are currently shooting for 95% availability and at 94.3% depot return rate from JEIM. They are currently using the following AGE:

- SCS tester (supervisory control)
- trim box
- SOAP
- Looking at EMS manual performance system.

(b) His information "wish" list for troubleshooting includes:

- FTIT clicks and margin
- FTIT spread
- rate of disc usage
- borescope inspection results.

(c) Currently, engines are being trimmed every 60 operating hours with depot returns averaging 400 hours.

(d) He believes EDS would give the Air Force the opportunity to do preventive maintenance to avoid catastrophic failure, to be "smarter" in trimming and fault isolation.

(e) Gas path deterioration analysis should allow the engine to run to a point where it needs to be pulled. Sensor failures must be discovered without generating anamolous maintenance requests.

(f) There is a major problem currently with F100 parts tracking because approximately every third component is cannibalized from other engines. This causes tracking system accuracy problems.

(g) Opportunistic build is an interesting future concept with a validated gas path capability and modular engines. Establishing module performance level on depot return is a problem, since no test cell data is available.

2.1.2.3 TAC Engine Manager

(1) Profile: Sgt. has experience in engine management specified in AFM 400-1.

(a) Engine managers are not required to be cognizant of engine maintenance procedures.

(b) The prime responsibility is to maintain accurate engine status information using AFTO 1534 forms input to the OCALC DO24 system.

(c) Currently TAC reports status in following categories:

- serviceable spare
- build up
- maintenance
- awaiting maintenance
- RAW
- ENMCS

(d) Other engine manager responsibilities include spare levels, war reserve, pipeline information inputs and resupply status.

2.1.2.4 Base Propulsion Maintenance Specialist

(1) Profile: This MSgt has experience working "about every" engine owned by the Air Force over the past twenty years. Specialties include wing maintenance efficiency analysis, and production. Recently he has worked the LWF and YF16 and YF17 programs at Edwards AFB, the F16 acquisition, J79 program development and F100 engine problems.

(2) Comments on maintenance information requirements:

(a) The system should be totally integrated. It should be usable by all base personnel down to the Airman 3 level at the line.

(b) Currently expertise is being lost at the base because the tech data is not equal to the weapon system requirements and training is not commensurate with the problem.

(c) The automated system is not the end item. Its design should understand the user's problem and let the user know about the problems of other users.

(d) Outputs should be formatted so that the maintenance person can interrogate the system at his level and utilize his experience. Give him the information but let him make up the story.

2.2 AIR LOGISTICS CENTER

2.2.1 Discussion Analysis

San Antonio ALC

(1) SA-ALC is responsible for the repair and overhaul of the T56, F100, J79, TF30, and TF39 engines. The large U-shaped building used for maintenance was designed for the overhaul process (complete disassembly and repair). An engine enters through one wing of the building and is routed through disassembly, cleaning, inspection, rework, assembly and is shipped through

the opposite wing. Modification will be required to redistribute work stations to make the facility better equipped for OCM. Currently, the F100 is the only engine maintained by OCM. Other engines are slated to be changed over in the next two years.

(2) The monthly work production quota for the F100 are 6 engines, 6 fans, 28 cores, 8 turbines, 6 gearboxes, 10 augmentors, 12 high pressure turbines. The depot is required to meet this production schedule.

(3) On-Condition Maintenance -- The objective of on-condition (or conditional) maintenance is to specify the repairs that are necessary to return an engine or module to serviceable condition (i.e., complies with established mission and safety standards). The performance of outstanding non-urgent TCTO's or other opportunistic maintenance on life limited components should only be prescribed when economical (e.g., when the engine is already disassembled to the level necessary to perform the additional work). In order to effectively implement this maintenance concept, the OCM team needs specific information on each engine/module returned for depot repair. A list of items was suggested as candidates for inclusion in the OCM oriented iformational displays. They include:

- removal reason and nature of malfunction
- diagnostic analysis
- overtemperature bands
- FTIT out of band
- performance trends
- borescope and test stand reports
- vibration history
- SOAP
- maintenance history
- outstanding TCTO
- balance of life on any time/cycle limited components

It will be essential to correlate the engine performance information via GPA with historic maintenance actions. This is the first step in establishing symptom/cause relationships to support the concept of OCM.

(4) An OCM team was observed during an evaluation session. The team indicated that the maintenance history was currently the most important factor in their decision process. The G337 products were referenced as needed. They felt if more comprehensive information were available on an individual basis, it would greatly improve the OCM process. Scheduling and the production quota seemed to be the drivers of the amount of opportunistic maintenance that was prescribed.

Oklahoma City ALC

(1) All concerned were convinced that engine diagnostics and trending could successfully be used to predict imminent engine failures, reduce secondary damage and reduce unscheduled maintenance. The statement was made that SAC has documented 100/100 "hits" in predicting incipient failure based on tracking EGT's, EPR's, TSFC, RPM, etc.

(2) Currently OCM is being used at OCALC on the J57 (B52 & KC135) and the TF30-P3. Some problems with data interpretation have been experienced. A lot of the diagnostic work is post failure analysis. No OCM or trending is currently done on the TF34 or TF41. LCF and hot time, reporting are the primary monitoring parameters.

(3) The major TF30 failure modes are currently:

(a) Fan Blade Failure Disk & Hub Cracking

(b) #1 Compressor outer burner case rupture

(c) Air Seals on Compressor Blades

(4) Current TF30 procedures are to track accumulated hours by S/N at the component level. For these principal components,

"K-Factors" which relate accumulated hours to flight equivalent hours are being developed. For example, 1 hour in the test cell during AMT testing might be equivalent to 2.35 flight hours on the fan blades.

(5) A general comment was made regarding data systems generated by AFLC in the past. It was felt that previous systems were too tailored towards data and information needed for logistics management. The survey questions should be carefully designed to specifically isolate the different data and information needs at each level -- depot, base and logistics, maybe even to the point of asking each user what his view of the differences in requirements are.

2.2.2 Personal Interviews

ALC Management

Comments concerning maintenance information systems and integration of automated data acquisition and performance analysis were solicited from the ALC operational management supervisor.

(1) Deployment and particularly which aircraft, installed engines and engine spares to send is an important operating scenario. Another important issue is the deployed G337 system.

(2) The "age of data" requirement will impact how frequently the base level data base will be updated. It will also impact the format in which the data is displayed. AFLC personnel experienced with managing the engine inventory at MAC indicated that the update frequency should be 24 hours.

(3) 99% of the time the only information required to manage engines are LCF counts, operating hours, diagnostics signatures, and cross reference of the engine serial number to aircraft tail number, base location, and Julian date. Multiple signature spreads, trends and other information would be available to selected users only on an exception basis.

(4) It will be important to identify any problems with the G337/MMICS interface. Some of the current problems are probably linked to the preparation of data forms manually by base management.

(5) There is a need to correlate GPA ("Health") rating with maintenance actions. For example, if blade and vane failures are attributed to higher temperatures, the flame profile and pattern may be an important indicator. The ALC operations supervisor feels there is a need to develop a statistical data base that makes a valid correlation between performance trends and maintenance action.

(6) He stated his philosophy that the engine management data base should be composed of a front-half and a back-half. The front-half is the local data at the base level in terms of hours, LCFs, and some weighted engine health signature(s). The back-half is composed of summary engine data for hours and cycle information by engine serial number and location. He stated firmly that the primary base level data displayed should include as a minimum:

(a) engine S/N

(b) aircraft number

(c) Julian date

(d) base location

(e) total engine hours

(f) LCF counts

(g) engine health signature.

He referred to personnel at Kelly who successfully managed the MAC engine inventory using these parameters. This data once laundered through the bases can be transferred to the depot through the MMICS network. Typically, the engine manager in MAC might need this data updated every 12 hours. However, the operational limit seems to be a 24 hour update cycle (that's what MMICS is designed to do).

(7) He seemed very concerned that we obtain realistic requirements from the engine manager and chief of maintenance level.

(8) System Requirements: He defined the following list of questions to be answered by the TEMS data base:

(a) What are the current values of the engine and module parameters? (see previous list)

(b) Has the engine been trimmed recently? How many times? (might also be interested in how much trim adjustment is remaining for temperature, EPR and speeds)

(c) Has this engine suffered from stagnation stall?

(d) How do a,b, and c relate to previous engine maintenance?

(e) Can previous engine and module data be correlated with previous parts consumption? (there currently appears to be some correlation between parts coming off AMT engines and parts from depot, e.g., % O.T. can be correlated with % blade replacement/repair.)

ALC Data Processing Specialist

(1) Profile: Since April 1977, the Lieutenant has been Project Engineer for the OCM Program at SA-ALC. He has served ten years of enlisted duty and has participated in the Air Force education commission program to earn a degree in mechanical engineering. Past assignments include HQ Command and Communications, Bolling AFB. He is familiar with the Maintenance Data Collection System (AFTO 349). His present duties involve user interface for the G337 engine parts tracking system for the F100.

(2) The MMICS software was designed to be programmer efficient, not user efficient. A four card format is required for the transfer of information from base to CDB. Input edits have been implemented to reduce input error and improve quality of MMICS data. 781-E Maintenance Data is now available via the MMICS TREs (transfer records). He reports that the voluminous TRE printouts are a cumbersome replacement at SAALC for the

old 781-E forms. According to a Msgt from the maintenance facility, the manually recorded data is held to be more reliable and accurate than the MMICS products.

(3) The history behind the location of the CDB at OCALC began with the MASIIS computer used on the C-5 aircraft program. When the IBM 360/65 was transferred to the Air Force, SAALC had wanted it on site because of their responsibility for C-5 maintenance. Instead the MASIIS was installed at OCALC. The original IBM 360/65 has been upgraded to a triplex unit. SAALC's IBM 1130 system is linked by a dedicated line to the OCALC computer facility.

(4) G337 is the parts tracking data system for the F100 engine. The base is responsible for updating G337 daily with information from the EHR. Currently, 94 time/cycle limited components are monitored. Two G337 products are used extensively for OCM decisions. They are the 3032 report (engine composition) and the 3017 report (life accrual). The 3017 form is used to direct opportunistic maintenance on the life limited components. It lists the life balance in cycles or hours for the 94 key components. Because of cannibalization and failure to report the serial numbers on replaced components, information in the G337 is often incorrect. When an engine passes through SAALC, serial numbers on the disassembled engine are recorded manually and compared with those on the 3032. G337 reports use tabular listings exclusively; the density of data is high.

(5) He describes OCM as being a totally subjective process. The team consists of personnel representing material management (an engineer and technician) and the maintenance facility (scheduling, quality control, production). A local engine manufacturer representative is often present. The current lead engineer is very qualified. OCM is dependent on thorough engine condition/performance information. This is currently unavailable to the team on a timely basis. He would like to see the following assembled in a comprehensive engine profile for OCM:

(a) removal reason (e.g., forced or caused)

(b) malfunction occurence

(c) maintenance document

(d) borescope report

(e) FTIT out of bands

(f) SOAP

(g) history (781-E)

(h) test stand report from base

(i) history of overtemperature bands

(j) outstanding TCTOs

(k) G337 products.

(6) The real impact of engine monitoring and improved engine management at the depot would be to increase the efficiency of moving the asset through the repair facility (this probably does not represent real cost savings unless the Air Force can support engines with less manpower). The performance data will remove some of the subjectivity from the OCM process. The big implementation problem will be how to convince the personnel to use the system.

(7) There are two scenarios for deployed squadron engine monitoring. Under the first there would be no terminal at the remote location. TEMS data would be flown back to the home base weekly. In the second scenario, the squadron would have a mini computer with a local data base.

2.3 HEADQUARTERS AFLC

2.3.1 Discussion Analysis

(1) Information currently available for engine management is not easily accessible in a format optimized for use in the

maintenance process. Previous Air Force engine data systems have been tailored to the requirements of logistics management. Because of the different functions of engine maintenance and logistics management, current data systems do not specifically address the informational needs of the maintenance managers. A key objective of the orientation visits is to isolate the particular engine data and information required for fault isolation and maintenance specification at the base and depot levels.

(2) The outputs of engine monitoring and trending must be correlated to engine maintenance concepts. Experience with currently implemented engine monitoring systems described by cognizant Air Force personnel supports this hypothesis.

(3) Implementation of turbine engine monitoring will impact base operations. The implementational aspect is the most critical element in the specification of requirements for an engine monitoring system. It is essential to factor in the potential impacts and identify any problems that may occur.

2.3.2 PERSONAL INTERVIEW

TEMS Program Manager

Comments concerning the future of performance monitoring in the Air Force and the potential impact on the logistics and support of engines were solicited from a TEMS program manager.

(1) Profile: As a Captain in the Air Force, he flew F-4's. He was a member of the F-15 site acquisition team at Luke AFB. During a two year assignment to the Air Force Aero Propulsion Laboratory, he was engine propulsion analyst for the F100. He also served as F100 EDS Program Manager and supported the F100 engine at the F15 SPO. Currently assigned to AFLC he is director of On-Condition Maintenance. He is involved with the development of policy and procedures for the A-10 and J-85 TEMS. He also is the AFLC coordinator for the F100 EDS Program.

(2) The A-10 system is the first attempt by the Air Force to implement a TEMS that functions in an operating environment.

(3) The single biggest failure of MADARS is the innundation of data. TEMS should be equipped for continuous monitoring but not continuous recording. In his opinion the recommendation to equip all TEMS with continuous recording capabilities is unsound. He feels that the continuous recording option should be reserved for only a small portion of the fleet and used at the AFLC level to identify needed improvements in engine design.

(4) The DDU concept is not unique to TEMS. The uniqueness is the information itself and the ability of the receiving data system to handle the flow of information.

(5) Acceptance of the CRT displays does not appear to be an insurmountable problem. Base and depot level personnel are familiar with tabular hardcopy information and are not currently aware of the options available with graphical displays. It will be important to educate them to the potential display options.

(6) He believes that a comprehensive management capability will ultimately improve the communication problems between the base and the depot. It will provide ALC, MAJCOM and Base Engine Managers with a common data base.

(7) It is conceivable that the Air Force may decide to abandon the current hardware for MMICS. This decision will be influenced in part by the software required to handle and process the engine performance data. He mentioned that it will be important to specify a backup mode for TEMS in the event that MMICS is down.

(8) He feels that with automated engine monitoring the Air Force will be able to do a better job of engine management with fewer people. The major impact at the base level will be a overall increase in the understanding of engine operations and support. At the depot level engine monitoring data will impact the practice of OCM. Depot and base level managers will

be working from a common data base, AFLC and the major commands will have more visibility into the engine management situation. They will have a better basis from which to perform surge analysis, predict global engine removal rates and workloads, and improve supply posture. Information from propulsion monitoring will also be helpful in the development of software to specify policy and procedures for opportunistic maintenance and optimal engine build.

(9) The time criticality of information required at the base level will be a prime driver in the specification of the system requirements.

(10) The engine manufacturer is performing the F100 Reliability Centered Maintenances (RCM) Analysis. They will be responsible for establishing hard time and fly to failure components, for setting inspection intervals and developing OCM procedures for the F100. He envisions that the performance data will potentially be used to feedback and update RCM standards set on the F100.

(11) In response to the question of system acceptance, he answered that he felt the field people (base level) were in dire need of help and for this reason they should be willing to use an automated system. The key will be to make it clear that the system will assist them in their daily work and provide useful information for workload scheduling and decision making. If we can get this concept across and if the displays we design are meaningful, then the system should sell itself.

(12) In general, the response requirements for data base updating is 24 hours at the base level. For longer term data (historic), at least one base level computer (CRT) should be able to interface with the MMICS computer.

(13) A general software design consideration should be the number of engines for which each engine manager is currently responsible. He commented that where the airlines have a ratio of 1 engine manager for every 200 engines, the Air Force currently has a ratio of 1/3000 engines. The summary engine health and

trending data should, therefore, be organized in a format suitable for simplifying the engine manager's workload and decision making.

2.4 MAJOR COMMANDS (MAJCOM)

2.4.1 Personal Interviews (HQTAC)

HQTAC TEMS Liaison

(1) Profile: During the lengthy career of this SMSgt, he followed the development of Northrop EHMS hardware from the initial test on the T38/J85 by the Air Training Command (ATC) at Randolph AFB. He has been instrumental in the application of the systems hardware on the A-10/TF34 at Myrtle Beach and the development of the service evaluation plan. This knowledge coupled with his expertise in engine maintenance management at the base, depot, and command levels made him a key source of input for the systems analysis.

(2) An extended interview was held to brief him on the program, discuss his survey response, and elicit his comments on additional scenarios and displays. His personal experience with the TEMS hardware was discussed and implementational aspects of a generic system within the Air Force maintenance/logistics framework.

(3) Comments on survey and maintenance information systems:

In both his written responses and the subsequent discussions, he strongly emphasized the need to correlate maintenance history with performance trends. In the survey displays only summary indicators of certain maintenance actions were provided with the trends. He indicated that this was inadequate. In order to understand the cause and effect behind these trends it would be necessary for shop maintenance personnel to have specific information on the procedures, and component replacement/repair that occurred during any maintenance action. This information is presently collected manually and available for MMICS. A mechanism must be established for cross-referencing relevant history with an appropriate interval of trended GPA performance data (e.g., last 100 operating hours) and providing the information to the user on a single display. One caveat that he placed on the available historical data was the issue of accuracy. He indicated that inaccuracy was induced from two sources: errors in actual recording of the data, and abbreviated descriptions of maintenance actions resulting in omission of important details.

He identified the requirements for enhanced diagnostic information on the engine profile. He felt that the diagnostic message on the sample displays was only marginally adequate. Suggested enhancements included peformance information related to the specific flagged event and a synopsis of the probable causes for the fault.

In general, he preferred the displays with denser information content. He indicated a number of additions and deletions that were consistent with the survey response (e.g., deletion of the spares rate from the base status summary, additional information on repair status of uninstalled engines, etc.). He had certain reservations with respect to management by exception, particularly as it related to data on the engine profile. He indicated that when an event triggered a highlighted message in the vibration or SOAP categories he would like to see the associated level (e.g. G/B 3.9 mils) before accessing a subsystem summary.

He prefaced his comments on the maintenance forecasting scenario by saying that performance trending and accurate prognostication are key to the application of true OCM. He pointed out that the use of the word "failure" on some of the displays had a bad connotation within the Air Force interpretation of OCM. "Failure" implies the principle of fly-to-failure, which is the very practice the Air Force is attempting to avoid via performance trending and OCM.

In addition to the monthly displays of time/cycle and performance removals, he identified the need to establish a watch status report. Its purpose would be to flag engines that exhibit step changes in SOAP or vibration or significant trends in degraded performance of net or module GPA. This display would identify those engines whose health should be currently monitored on a regular basis (e.g. every other day, weekly). The watch status report would enhance the manager's capability to anticipate near-term maintenance on an individual engine basis. The benefits of such a capability would be twofold:

- identification of incipient failures and projection of required repairs and replacements;
- extraction of the maximum life from an engine, module, or component without operating the asset to the point of failure or severe degradation.

Besides citing the engine serial number, installed aircraft tail number, and watch status reason, the report should include other engine usage factors (e.g., time/cycles, HST I/II) that might be instrumental in potential specification of a maintenance action. These factors would be a subset of the information normally available from a sort request. (In effect the watch status report is an automatic sort on all installed engines whose status has been designated as watch.)

The watch status report allows base level shop management to make more effective use of their time. By crearing an engine status that falls between full mission capability and alarm condition (critical), the manager is alerted of a significant but non-critical shift in a monitored performance or usage factor. The watch status display identifies those engine profiles and relevant subsystem summaries that currently require careful monitoring and regular access by the manager. This supports the management by exception concept, i.e. selective identification and access of engine profiles.

In terms of deployent scenarios, he identified that engine health/condition is only one element of the selection process. Generally, mobility planning identifies a group (e.g., squadron) of aircraft that are FMC and properly configured for the deployment scenario. At that point the wing chief of propulsion would be asked to assess the engine health and recommend the aircraft to support the deployment requirements. Under these procedures a joint GPA ranking would be applicable only after sorting the engine files based on the eligible aircraft. For a multiple base deployment, HQTAC generally tasks each base to provide a certain number and type of aircraft and spare engines. The interactive deployment planner would probably be more applicable at the base level.

HQTAC Maintenance Officer

(1) Profile: This USAF Captain served as a maintenance officer for a F111 wing under a POMO. He was recently assigned to the engine monitoring group at HQTAC, Langley AFB. He will be following the A-10 TEMS program at Myrtle Beach.

(2) EHMS/TEMS appears to cause maintenance. In the Air Training Command (ATC) demonstration at Randolph AFB, TEMS "cost" more manpower at the base level. The problem with the ATC experiment was that there was really no control placed on the "control" group. ATC operates a reliable, mature engine. The maintenance personnel were experienced. ATC characteristically has less manpower turnovers than any other command. Engine problems flagged by the TEMS were identified by the skilled maintenance staff. The report that resulted from the ATC TEMS experiment was not supportive of engine monitoring. Recent documents from ATC reveal that the command has altered its position and has taken a "pro-diagnostics" stance. The TAC mission is conducive to monitoring because the mission impacts engine health. During the Holloman TEMS tests, pilots reported discrepancies often occurred when the aircraft was being operated outside the established profile. TEMS data was used to verify this.

(3) He compared the implementation of SOAP to engine monitoring When SOAP was first introduced as a maintenance tool at the base level, there was wide-spread skepticism. Today, SOAP has become an accepted indication of engine health. Performance monitoring should offer the same sort of benefits if properly implemented. He feels that automated monitoring may very well be the SOAP of tomorrow.

2.4.2 Personal Interview (SAC)

Former SAC Engine Manager

(1) Profile: As a USAF Captain, he served as a maintenance officer in SAC. He has experience working in both the supply and maintenance organization at the base level. He also served as a SAC squadron commander. His next assignment was as SAC Engine Manager. The bases in his command operated TF33, TF30, J85, and J57 engines. As SAC EM he was responsible for calculating stockage objectives for spare engines and monitoring base supply status over the year. He served on the Aerospace Engine Life Committee/Engine Logistics Planning Board and participated in the twice yearly formulation of actuarial factors. He joined HQAFLC in July 1978 after retiring from the Air Force. He is currently involved with AFLC's program on the enhancement of the pipeline and actuarial sytems (CEMS Increment III).

(2) A typical SAC operating scenario is flying out on an exercise and landing at an intermediate location for fuel and returning to the home base. Under the peace-time operating scenario, 1/3 of the engines are on alert, 1/3 are assigned for training, and 1/3 are in maintenance. The SAC EM tracks the location and operational status of all engines assigned to his command.

(3) The issue of war surge analysis is of critical concern to the MAJCOM EM. Under war conditions engine flying hours increase by two to five times the peace-time rate. How does

this affect engine failures? Are current spares to installed ratios adequate under this scenario (e.g., 18% J57, 12-14% for TF39 and TF33)? Can the pipeline handle increasing failure rates and decrease turnaround time on engines? He used a Fleet Management Information System (FMIS) that he developed at SAC to monitor base/engine asset posture.

(4) He is familiar with the SAC engine condition monitoring program from the management side. He thinks that the most successful aspect of the program was that base personnel were tracking engine performance while they were operating. A major problem for SAC is to decide in what direction the condition monitoring program should go now. He suggested that SAC might use the data to carefully examine the impact of operating time on an engine.

The user requirements at the lower level (base) will drive the requirements for information at the higher levels (depot, MAJCOM). A time slice report would be of real value to the base level engine manager. The overall Air Force engine management objective is to maintain a creditable readiness posture with an ever tightening budget.

(6) Automated monitoring will not go on older engines. It will fly on newer models particularly fighters. The most important impact is that it will improve the manager's ability to schedule workloads for maintenance and supply activities.

(7) Training and skill level problems may become implementation obstacles. Within SAC there is generally good job longevity at the base level. Acceptance of the CRT display will take some training. It will be necessary to have a central system to share the overhead (e.g., cost, management) of automated management system.

(8) He pointed out that OCM is not an entirely new concept. Certain aspects of OCM have been practiced within the overhaul process. The new approach is however more structured and requires more information.

(9) Important MAJCOM engine manager requirements at SAC include:

(a) Calculating and comparing engine spares/installed ratios on a yearly basis for various aircraft.

(b) Monitoring and adjusting spares/installed as required to meet operational readiness criteria.

(c) Holding up engine assets.

(d) Supporting Logistics Planning Board Activities.

(e) Examining actuarial factor changes (twice yearly).

(f) Answering day-to-day questions.

(10) Questions typically asked at the SAC level are related to longer term time related engine and aircraft management decisions. For example, how many aircraft (engines) of a given type are currently available (or being used for) military exercises?, deployment?, and/or remote operations support?. Technical engine related (OCM) problems have to be dealt with on both a supply and cost basis as well as scheduling. For example, suppose the TF30 outer combustor cases are consistently breaking. The SAC responsibility falls in the areas of predicting the catch-up time required to find and retrofit all operational engines. Also, procedures must be developed for maintaining tighter inventory control on these "weak links" in order to keep the spares/installed ratios reasonable.

(11) <u>System Requirements</u> -- The following TEMS "wish list" was developed through these discussions:

(1) Engine status summaries at the base and depot level should be displayed. Serial numbers and location at the very least.

(2) Historic and current asset posture trending capability vs. calendar years is a primary evaluation tool during budget cuts.

(3) Number of engines required per flying hour is another supply parameter.

(4) Displaying number of spared or spares/installed ratio at the module level in a "Pie Chart" format would be extremely useful. This would show at a glance what percent of dollars time, etc., were being expended on fans, combustors, afterburners, etc.

(5) Removals/month is also a vital parameter on a per base level.

(6) Throughput days at JEIM is also tracked by engine type.

(7) The critical need for a comprehensive management system is to achieve commonality in usage parameters (data), codings, and communications between the base, the depot and the MAJCOM. The depot and the supply personne must use the same working data or the system will not be effective.

(8) A critical requirement at the base level is to develop a better parameter or technique for predicting required engine maintenance and therefore maintenance workload. Currently, time (flying hours) is used but is not an accurate indicator. In general, 75-80% of current engine removals are premature, that is, non-max time.

2.4.3 Personal Interview (ADC) Engine Manager

The ADC mission is continental defense under the Chief of Staff of the Air Force. Base of operations is therefore CONUS and alert detachments are deployed across the country. ADC is actually a tenant on each base. Engine histories were kept manually and data management was primarily via telephone lines.

(1) Profile: He served at the depot as engine manager for the TF33 and TF41 engines. His next assignment was at the Air Defense Command in the Directorate of Maintenance as an engine manager. He has experience there with the J75, J57, and J33 engines. He joined AFLC in June 1978.

(2) The primary mission of ADC is CONUS defense. ADC is a small command (6 bases, 1 training base). ADC is a tenant on all but two of its bases. There are 19 UE (Unit Equipment-single engine aircraft) assigned to the operating bases and 24 at the training base.

(3) ADC deploys alert detachments for cross-country missions. An important responsibility of the engine manager is to assure that his alert aircraft are supported. Because alert detachments operated under a "no-maintenance concept" the rule of thumb was to have one operationally ready engine available for each aircraft on alert status.

(4) ADC base level maintenance used pilot squawks (e.g., stalls, vibration), SOAP, EPR, EGT, hot starts, and crew squawks to identify and direct maintenance actions. Trim problems are more critical on a single engine aircraft. A notebook containing maintenance/performance history on each engine was kept in the engine shop. Operating time was recorded on chalk boards also located in the shop. Engines for installation were chosen commensurate with aircraft time. Engines (except for MOT) were NRTS only after the evaluation of the maintenance technicians and the approval of the command.

(5) As ADC Engine Manager, he tracked spares availability, condition of engines in work and the number of ENORS (now ENMCS). Component problems were cyclic in nature and required tracking of critical parts. Because of the small size of ADC he maintained daily contact with the bases via phone.

(6) He thinks that the primary impact of TEMS will be the accuracy of documentation and the timeliness of information. He thought there would be little resistance to CRT displays at the base level. In ADC there is good job longevity for personnel at the base level.

(7) He was able to achieve a less than 20% NORS rate over a two year period. ADC essentially tracked and managed engines by reliability techniques. Every 3-4 weeks an engine status would be prepared which included:

- Spares available
- Condition and status of engine in-work (base and depot)
- NORS rate
- Days remaining before NORS impact.

(8) He described the major role of an automated monitoring as keeping engine time in sync with aircraft time for single engined aircraft. Critical maintenance and long lead time parts such as A/B welds and manifold fixes, can be done opportunistically, but were driven by parts supply, pipeline and work scheduling criteria.

He felt that a remote CRT would have been "handy" for TCTO work, etc., but that he could have done his job effectively without it if given a few more telephone lines.

His opinion of the major impact of an automated TEMS would be on:

(a) Documentation at the shop level (re: checklist)

(b) Maintenance history logs

(c) Summary MOT data for the shop chief

(d) Serialized control of parts.

In regard to (d), he said that he experienced a cyclic occurrence of maintenance problems on particular engines. That is, something you thought was changed would either not be modified on a particular S/N engines or the fix would prove inadequate.

In general, he felt that the MMICS concept was viable and would be accepted at the base level as preferable to manual "paper shuffling", e.g., AFM66-1 forms.

APPENDIX B
SURVEY DESIGN AND ANALYSIS

I. SURVEY DEVELOPMENT

The information system for automated engine monitoring will have hierarchical design. Access to data is controlled by certain key functions. SCI (Vt) developed the TEFDI survey around index, profile, alarm, and forecasting functions.

There are three index functions, viz., finding, ranking, and grouping. Finding refers to accessing engine files according to a particular attribute (e.g., serial number, operational status, location, operating hours above or below a specified limit, etc.). Finding displays list all engines possessing the user specified attribute. Ranking refers to ordering engine files according to numerical attribute (e.g. GPA rating, operating hours, LCF counts). The ranking displays list the engines with the desired attribute and in the order requested by the user. One objective of the survey is to determine which elements of the individual engine file are needed to make the management decisions that require sorted and ranked data. The grouping function refers to the tabulation of engines possessing certain attributes (e.g., number of installed F100's, number of engines awaiting maintenance). Examples of grouped displays include summary of the operational status of all engines at a particular base or the status of all bases within a certain command.

Access of individual engine files by serial number is called the profile function. The profile summary contains the engine's vital statistics. Additional information is obtained by requesting various subsystem functions (e.g., GPA trends, vibration history, SOAP charts, engine build, etc.). The profile summary contains the quantity of information normally needed to manage the engine. Subsystem displays are accessed by the user on an exception basis.

The survey scenarios were directed towards determining the information to include in the profile summary and the types and formats of information to offer in the subsystem displays.

Engine monitoring systems provide the capability for an alarm function at the base level. The alarm is the identification of a detected fault on a specific engine. The engine manager then accesses the profile summary and relevant subsystem displays for that engine.

A forecasting function has been identified as a possible requirement for engine logistic support. A number of the survey scenarios that relate to depot and MAJCOM level decisions contain an element of forecasting. Survey questions were formulated to identify specific requirements for the forecasting function in the system specification.

The key functions that control data access are index, profile, alarm, and forecasting. Table 1 cross-references each of the eleven decision scenarios with the functional modes that were demonstrated in the display systems. The three index functions are grouping, ranking, and finding. The grouping function appears with five scenarios (QA, QC, QE, QJ, QK), the ranked with two (QA, QI), and the find with six (QA, QD, QE, QI, QJ, QK). The engine profile appears with three scenarios (QB, QC, QG); several examples of subsystem summary displays accompany two of the profiles (QB, QG). The alarm function is illustrated with one scenario (QC). The forecast function is demonstrated in three scenarios (QF, QH, QJ). The utilization of this particular combination of data access functions supports the hierarchical design of the required management information system. Table 1 also identifies the relevant management level to which each of the scenarios were directed. Six of the scenarios concentrate on base level operations. Two focus on depot specific procedures. Three scenarios address command level management decisions. The concentration on base specific scenarios is due to the fact the requirements of the base level users will drive the system requirements for turbine engine monitoring.

Table 1
Scenario Summary Cross-Reference

SCENARIO	LEVEL	FUNCTIONAL MODE	DISPLAY FORMATS	PROCESSOR REQUIREMENTS
0A-Bare Base Deployment	Base	Index-Group; Index-Rank; Index-FIND	Tabular	TEMS; Base Processor; MMICS Interface
0B-Pilot Squawk	Base	Profile; Subsystem Summary	Tabular Graphical	TEMS; Base Processor; MMICS Interface
0C-Engine Alarm	Base	Index-Group; Alarm; Profile	Tabular	TEMS; Base Processor; MMICS Interface
0D-TCTO Management	Base	Index-FIND	Tabular Graphical	TEMS; Base Processor; MMICS Interface
0E-Squadron GPA Degradation	Base	Index-FIND; Index-Group	Tabular Graphical	TEMS; Base Processor; MMICS Interface
0F-Base Maintenance Forecast	Base	Forecast	Tabular; Graphical	TEMS; Base Processor; MMICS Interface
0G-OCM Team	Depot	Profile; Subsystem Summary	Tabular; Graphical	Transfer of Engine Records to CDB; CDB Access
0H-Maintenance Forecast	Depot	Forecast	Tabular	CDB Access; Interactive Capability
0I-Multiple Base Deployment	Command	Index-FIND Index-Rank	Tabular	CDB Access, MAJCOM Processor; Interactive Capability
0J-TCTO Assessment	Command	Index-FIND; Index-Group; Forecast	Tabular; Graphical	CDB Access, MAJCOM Processor
0K-Spare Engine Status	Command	Index-Group; Index-FIND	Tabular	CDB Access, MAJCOM Processor

The formats used to design the displays for the scenarios are also specified in Table 1. Each scenario has at least one tabular display system (AF personnel are most familiar with tabular listing of data). Bargraphs and plotted or trended data are examples of graphical formats. In six of the display systems, survey participants evaluated graphical alternatives.

Processor requirements indicate the hardware and data flow necessary to support the display systems for each scenario. A basic assumption in the information system design is the existence of a generic monitoring system. The base must also possess the capability to reduce and process the TEMS data. Integration of the performance/GPA information with additional usage factors (e.g., time, cycles, SOAP, etc.) requires an interface with the MMICS computer. Depot and command level engine maintenance management require the automatic transfer of engine records from the base to the central data bank (CDB). The MAJCOM's would access portions of this information for analysis via their own computer.

II. SURVEY DISTRIBUTION AND PARTICIPANT SELECTION

The survey was modular and composed of eleven self-contained sections. Participants received a subset of the eleven sections. The determination of each subset was based on the participant's knowledge and relevant operational experience in engine maintenance/logistic management.

The survey participants were selected via personal contact during on-site visits to SAALC, OCALC, AFLC, HQTAC, Langley AFB and Myrtle Beach AFB. The individuals are a representative sample of base, depot, and command engine management. Table 2 contains a list of the Air Force participant experience and question distribution. Relevant operational experience in engine maintenance/logistics management (i.e. base, depot, command) is specified for each individual. The entries in Table 2 indicate the subset of scenarios that were sent each participant. The selection of the appropriate scenarios was based on several underlying objectives and critical constraints.

Table 2
Survey Question Distribution by Participant Experience

NUMBER	EXPERIENCE BASE	EXPERIENCE DEPOT	EXPERIENCE COM.	BASE A	BASE B	BASE C	BASE D	BASE E	BASE F	DEPOT G	DEPOT H	COMMAND I	COMMAND J	COMMAND K
1	•		•	•		•		•				•		
2	•		•		•			•	•			•	•	•
3	•	•				•		•		•	•			
4	•				•		•	•	•					
5	•	•	•	•		•				•	•	•		
6	•	•	•		•		•	•	•		•	•	•	•
7	•		•		•	•	•	•	•					
8	•	•	•		•	•		•		•	•			
9	•	•	•	•	•			•				•	•	•
10	•		•	•		•		•	•			•		
11	•	•				•				•	•			
12	•	•	•	•		•	•		•	•	•			•
13	•		•	•		•	•							•
14	•		•	•	•			•				•		•
15	•				•	•		•	•					
16	•	•	•		•		•			•	•			
17	•					•	•		•					
18	•		•	•			•						•	•
19	•		•	•	•			•	•					
20	•			•	•	•	•		•					
21	•			•		•	•		•					
22	•			•	•	•	•							
23		•	•		•					•	•		•	
24	•			•	•		•		•					
25	•		•		•	•			•			•	•	•
26	•		•		•				•			•	•	•
27	•			•	•	•		•						
28	•	•	•		•	•		•	•	•				
29	•		•				•					•	•	•
30	•			•	•	•	•	•	•					
31	•	•				•		•		•	•			
32	•	•	•		•	•		•	•	•				
33	•	•			•	•			•	•				
34	•		•	•	•	•		•				•		
35	•	•	•	•	•					•	•			
36	•		•	•			•						•	•
37	•	•			•		•	•		•	•			
38	•	•	•			•		•	•					
39	•	•			•					•	•			
40	•					•	•		•					
41	•	•	•	•		•	•		•					
42	•	•	•	•		•		•				•	•	
43	•			•	•									
44	•			•	•									
45	•			•	•									
46	•			•	•									
47	•			•	•									

2.1 Consistency with Participant's Knowledge and Experience

All participants were identified to have a working knowledge of base level operations from either the view of maintenance management or logistics support (e.g., supply, planning and scheduling, parts tracking, MMICS). Participants with a more extensive background in the in the logistical aspects of engine operations were given base level scenarios in forecasting (QF), TCTO management (QD), and deployment planning (QA). Individuals familiar with the higher level aspects of maintenace management were given the sections that corresponded closely to their specific experience (e.g. QA-Bare Base Deployment, QE - Squadron Performance Degradation, QF - Maintenance Forecast). All Air Force participants received scenarios QB and/or QC because these sections investigated the diagnostics/engine alarm capability and the concept of performance trending via the gas path average.

In the course of the on-site interviews, several people recommended inclusion of airmen level responses in the analysis. For this reason, engine shop representatives at the 1TFW and 354 TFW were sent additional surveys for distribution to selected airmen in their propulsion branch. The special airmen surveys were limited to the base level scenarios that were directly maintenance oriented (QB and QC).

Thirty-two of the survey participants (68%) were identified as also having experience at the depot and/or command levels of engine maintenance/logistics management. In addition to the base oriented survey sections, they received selected scenarios from QG through QK.

2.2 Concentration on Base User Requirements

Because the operating base is the logical location to manage the individual engines, its user requirements will drive the specification of the system requirements for engine monitoring. The TEFDI survey, therefore, was designed to focus on the critical issues of base level engine management. Over half the scenarios specifically addressed maintenance and logistics decisions that were relevant at the base level. Selection of each participant's subset of question was weighted heavily towards these scenarios (QA through QF).

2.3 Coverage of Access Modes and Display Types

Every effort was made in the selection of the scenarios to insure that the survey population would be exposed to the range of capabilities and potential options available via an integrated engine monitoring/management system. Table 3 indicates the percentage of the survey population that evaluated some of the key displays and access modes illustrated in the survey.

2.4 Participant Time Constraint

Because of the time and effort required to respond to the questionaire, an attempt was made to limit each participant's survey to four or five scenarios. This limit placed a constraint on the response coverage, particularly at the command level. For that reason, selected participants with experience at multiple user levels recieved more than five sections.

2.5 Engine/Airframe Manufacturer Participants

Five surveys were assembled for members of the engine and airframe manufacturing community. One was sent directly to McDonnell Douglas. The other four were forwarded for distribution to representatives of Pratt & Whitney, General Electric, and Detroit Diesel Allison Companies.

III. SURVEY ANALYSIS

The following section contains an annoted copy of the survey with discussion of the development of each section.

3.1 Survey Introduction

The survey contains a short information section that includes participant background, general instruction, a sample question, and a glossary of terms used throughout the survey. The information

Table 3
Survey Participation By Key Display Types

Participation	Display Type	Scenario
81%	Base Status Summary	QA, QC
100%	Engine Profile	QB, QC, QG
66%	Alarm Capability	QC
100%	Diagnostic Message	QB, QC, QG
79%	GPA Snapshot and Trend	QB, QG
40%	Base Engine Removals	QF
79%	Forecast Capability	QF, QH, QJ
100%	Base Index (Rank, Sort, Group)	QA, QD, QE
40%	Command Index (Rank, Sort, Group)	QI, QJ, QK
26%	Command Status	QK

Table 4
Glossary

GLOSSARY	
ALARM	Alarm is a report from the monitoring system that an engine is performing outside the limits of normal operation.
AUG	Augmentor module.
AWM	Awaiting maintenance.
CORE	Core module.
CYCLES	The number of major throttle transitions.
DELTA TIT (ΔTIT)	The remaining temperature uptrim capability measured in control adjustment ratchet clicks.
ECP	Engineering Change Proposal.
EDS	Engine Diagnostic System is an on-board device that automatically monitors and selectively records engine operating data for diagnostic purposes.
EEC	Engine electronic control.
ENMCS	Engine Not Mission Capable due to Supply.
EOT	Engine Operating Time measured in hours.
FMC	Fully Mission Capable.
GPA	Gas Path Average is a measure of an engine's performance relative to a new unit.
HPT	High Pressure Turbine module.
HSI	Hot Section Inspection refers to maintenance periodically performed on the core module.
HST (I/II)	Hot Section Time at temperature levels I and II is either measured in hours or as a % of total engine operating time.
LCF	Low Cycle Fatigue measured in cycles.
LIFE LIMIT	Life Limits are hour or cycle limits that require the replacement of a component.

Continued...

Table 4 (continued)

MAINT	In Maintenance.
NMCS, NMCM, NMCB	Not Mission Capable due to either Supply, Maintenance, or Both supply and maintenance.
PMS	Partially Mission Capable.
SERV	Serviceable engine.
SOAP	Spectrometric Oil Analysis Program determines the metallurgical composition of engine oil. Changes in metal composition indicate engine wear.
SPARES RATE	% ratio of uninstalled to installed engines.
SQUAWK	Pilot-reported engine deficiency.
TCTO	Time Compliance Technical Order.
TMS	Type, Model, and Series.
TOT	Total engine Operating Time measured in hours.

section is shown in Table 4. Table 5 is an excerpt from the survey instructions. It discusses the purpose of the survey and introduces the concept of the automated management system (AMS). Participants are asked to assume the existence of a video terminal that allows them to access information from the AMS. The GPA (gas path average) is defined and identified as the measure of engine or module performance.

Table 5
Survey Instructions

— INSTRUCTIONS —   This booklet contains a survey that will be used to help determine how automated engine health monitoring can be used to increase the efficiency of Air Force engine maintenance support. Answer the questions based upon your job experience and feel free to comment in the spaces provided. We will use both the question responses and the comments to assemble system requirements based on your needs.   The survey is composed of a group of self-contained sections. Assume that you have a video terminal at your work station that allows you to communicate with a central computer which we have called the automated management system (AMS). Each set of questions is based upon the information presented on the video terminal during interaction with the AMS. We have reduced the size of the video screen for the survey. Imagine a full size display when you are considering your answers.   An important goal of the survey is to evaluate the possible impact of engine performance monitoring on the support process. We have used a generic <u>derived parameter</u>, GPA (gas path average), to represent the output of an engine performance monitoring system. Consider that GPA measures engine or module performance relative to a new unit. Thus, GPA = 100% represents acceptance performance and GPA = 0% represents the lowest performance experienced in any engine.

Each section includes the decision scenario and the accompanying display system(s). Each display system contains one or more screens of information. A set of questions follows each display system. These questions are directed towards the specific format and information content of the display screens. A final set of questions appears on the last two pages of each subsection. Figure 1 and 2 are examples of the question set. Survey particpants are required to rate each system according to clarity, information content, and effectiveness. Participant response was used to determine overall attributes of the display system. In the clarity category the particpant identifies the ability to recognize and understand the data display. In the information content category he ranks displays according to the amount of information required to make the management decision introduced in the scenario. In the effectiveness category the participant is comparing the display system presentation relative to current procedures for engine operations and support. Participants are also given the opportunity to swap screens between display systems and to design their own displays on a blank screen.

3.2 Analysis of Survey Displays and Questions

The following paragraphs analyze each of the eleven question sections. Each scenario is presented and its objective discussed. The formulation of the data displays summarizes the information density, display format, and any special techniques demonstrated. The analysis concentrates on the relationship between the display systems, the functional modes demonstrated, and the questions asked. The accompanying figures are from the survey.

— INSTRUCTIONS —

We are interested in determining some of the overall attributes of the Display Systems you have just examined. Before you answer the questions below, leaf through the pages of this section one more time to refresh your memory of the scenario and each Display System.

We want you to rate the CLARITY, INFORMATION CONTENT and EFFECTIVENESS of the system relative to the management objective posed in the scenario. The ability to recognize and understand the data display visually, defines the system's CLARITY. Tabular data too densely packed, poorly defined data plots and ambiguous column headings would detract from the overall CLARITY of a display. The amount of information or data used to perform the scenario management function is ranked by INFORMATION CONTENT. A display system can have too many or too few categories of data to solve the posed problem. A Display System's EFFECTIVENESS measures the ability to use the data as presented. Rank the system relative to how the job is currently done. For example, if you can solve the scenario problem more quickly, conveniently and with more confidence than at present, you would rank the system more effective.

Check the categories that best represent your evaluation of each Display System.

	DISPLAY SYSTEM A	DISPLAY SYSTEM B
CLARITY	very clear __:__:__:__:__ obscure	very clear __:__:__:__:__ obscure
INFORMATION CONTENT	too much __:__:enough __:__:__ too little	too much __:__:enough __:__:__ too little
EFFECTIVE-NESS	more effective __:__:same __:__:__ less effective	more effective __:__:same __:__:__ less effective

Now that you have ranked each system separately, judge which Display System is best in each category.

	SYSTEM A	SYSTEM B
CLARITY	___	___
INFORMATION CONTENT	___	___
EFFECTIVE-NESS	___	___

Figure 1 Survey Instructions and Questions

Would replacing a screen in Display System A with one from System B make System A more effective?

______ no ______ yes (Specify: ________________________)

Would replacing a screen in Display System B with one from System A make System B more effective?

______ no ______ yes (Specify: ________________________)

— OPTIONAL —

Use the blank screen below to design a display to replace one or more screens presented in the previous pages.

Replaces screen(s): ____

Comments: ____

____

____

Figure 2 Survey Questions Format

3.3 QA-Bare Base Deployment

Scenario:

HQUSAF has given TAC a requirement of deployment to a remote location. Mobility Planning has ordered Langley AFB to deploy 10 serviceable F15's and five spare F100's in 48 hours. This will be a bare base deployment with minimal maintenance support (if an installed engine cannot be repaired at the flightline it will be removed and replaced with a spare). Over the two-week deployment, aircraft are scheduled to fly two sorties per day. Langley's Chief of Maintenance and the Chief on the Propulsion Branch must recommend to TAC which aircraft and spares to deploy. To make this recommendation they need to know which of the fully mission capable aircraft are equipped with the best engines. Any aircraft that is deployed should have a balance of life (on all time/cycle limited components) to support the sortie rate. The Chief of Propulsion needs to know the status of his serviceable spares to determine whether installed engines must be pulled to obtain the five F100's necessary to deploy.

Scenario Objective:

This scenario is used to illustrate three index functions; grouping, ranking and finding. The user is provided with a current status of the base's engines and aircraft via a grouped display. Ranking aircraft, according to the attribute of joint engine performance, provides a list of aircraft equiped with the highest performing engines. Additional engine information (time, cycles, trim adjustment, atc.) supplies the user with supporting data for his recommendations. Requesting the AMS to sort the base engine files, allows the user to identify the serviceable spares available for deployment.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide an updated report on Langley's status. The base status summary (screen A-1) appears. It shows the status of aircraft and engines assigned to your base.

AIRCRAFT are classified according to mission capability.

Uninstalled engines are identified according to repair status.

Based on latest flightline data, no engines are in alarm status.

SPARES RATE is % ratio of uninstalled to installed engines.

SCREEN A-1

BASE STATUS MONITOR SCI(VT)

LANGLEY AFB

PAGE: LAST UPDATE: 7?JUN86

AIRCRAFT	72 F15	ENGINES	148 F100
FMC	60	INSTALLED	130
PMC	6	UNINSTALLED	18
NNCS	3	SERV	3
NMCM	2	MAINT	6
NMCB	1	AWM	3
		ENMCS	6
ALARMS: NONE		SPARES RATE	14%

COMMAND:

You now request the AMS to rank (in descending order) your F15's by combined engine health (Joint GPA is an average of both engines' health ratings). Screen A-1 appears. The next 10 ranked aircraft can be displayed by a simple terminal input.

STATUS refers to the mission capability of the aircraft. A/C 119 has an avionics problem, but its engines have high performance ratings.

Engine position is given as left or right. Time, trim status (ΔTIT in clicks remaining) and serial number are given for each engine.

Component LIFE LIMITS (e.g. 9000 CORE) appear only if they will occur within the next 100 operating hours.

SCREEN A-2

BASE STATUS MONITOR SCI(VT)

LANGLEY AFB

PAGE: LAST UPDATE: 7?JUN86

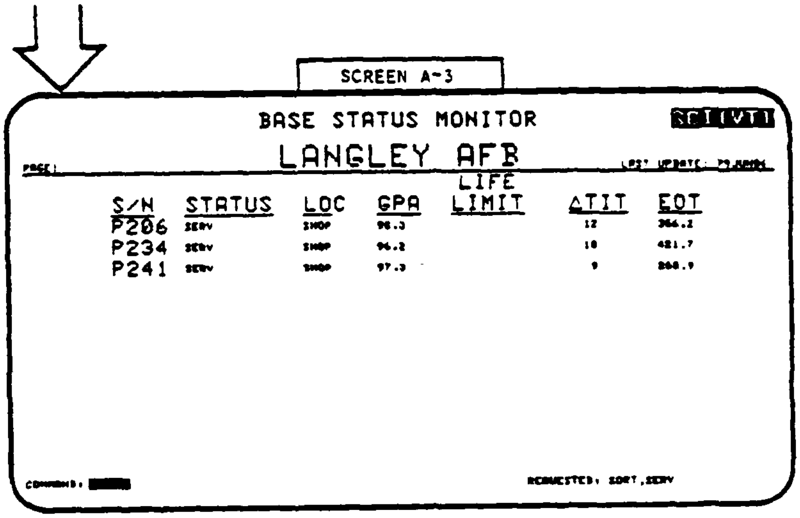
JOINT GPA	A/C	STATUS	S/N L	S/N R	LIFE LIMIT	ΔTIT L	ΔTIT R	EOT L	EOT R
98.7	131	FMC	P141	P162		10	12	501.4	621.3
97.8	156	FMC	P203	P216		10	9	432.1	329.3
96.3	119	PMC-AVI	P192	P114		10	12	422.3	621.1
94.8	172	FMC	P165	P149	[illegible]	11	8	521.2	303.2
93.5	141	FMC	P234	P201		10	12	302.1	291.1
92.4	162	FMC	P184	P100		8	9	391.2	481.3
90.7	191	FMC	P081	P431		12	12	282.3	201.9
90.7	181	FMC	P341	P602		9	10	421.3	301.2
90.3	129	FMC	P332	P119	[illegible]	11	11	421.4	621.3
88.7	137	FMC	P262	P122		9	10	298.3	232.9

Figure 3 Survey Module QA   PROCEED TO NEXT PAGE

DISPLAY SYSTEM A (CONTINUED)

You request the AMS to indicate the serviceable spare engines currently at Langley AFB. Screen A-3 appears.

SCREEN A-3



The system request is repeated for reference.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen A-1 is a base status summary. Its purpose is to provide you with the information to make a quick assessment of the base's status. Rate the information content of screen A-1.

   too much ________ : ________ : ________ (enough) : ________ : ________ too little

2. Is there any information you would eliminate from screen A-1? If so, mark through it directly on the screen.

3. Is there any information that could have been added to increase the effectiveness and clarity of screen A-1? If so, write these additional items on the screen.

4. Screen A-2 ranks the aircraft on engine health. Rank the effectiveness of using GPA as a ranking factor for the deployment scenario?

   very valuable ____ : ____ : ____ : ____ : ____ worthless or ____ unable to score

   like ____ : ____ : ____ : ____ : ____ dislike or ____ unable to score

5. Component LIFE LIMITS only appear if they will occur within the next 100 operating hours. What do you prefer?

   ____ The 100-hour cutoff used on screen A-2

   ____ Another hour cutoff (specify: ________)

   ____ The component closest to its life limits regardless of time/cycles remaining.

6. Comment on Display System A.

   ____

   ____

   ____

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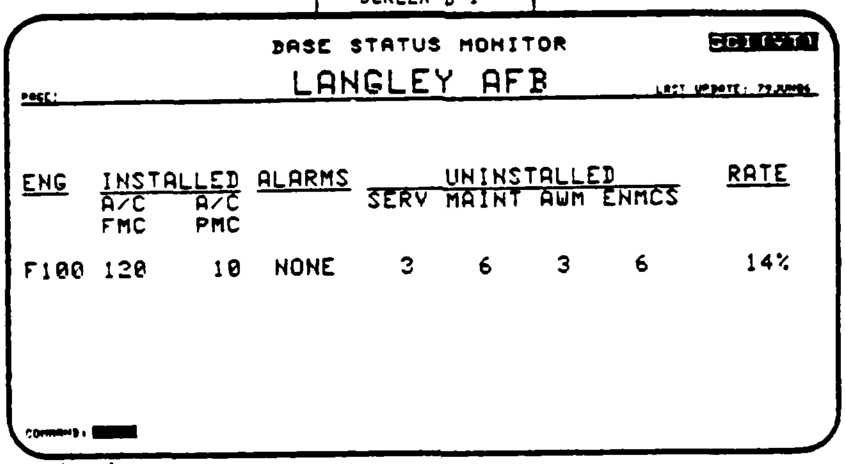
Figure 4. Survey Module 9A

DISPLAY SYSTEM B

You request your AMS to provide an updated report on Langley's status. The base status summary (screen B-1) appears. It shows current engine status and location.

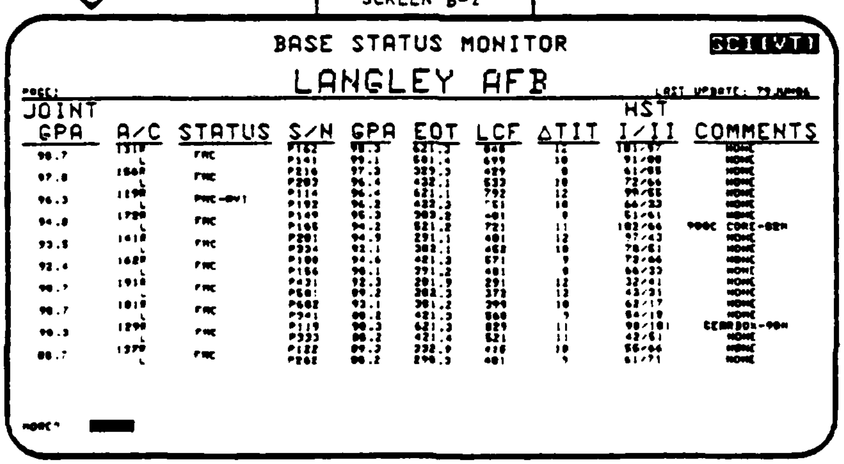
SCREEN B-1



You now request the AMS to rank your F15's by the JOINT GPA rating (the average of the two engines' GPA ratings). Screen B-2 appears. The next 10 ranked aircraft can be displayed by a simple terminal input.

SCREEN B-2

STATUS refers to the mission capability of the aircraft. A/C 119 is PMC for an avionics problem.



Individual GPA rating, engine operating time (EOT), cycles (LCF), and trim status (by clicks remaining) are given for each engine. Hot section time (HST) is given in hours.

The COMMENT column is used to indicate components within 100 operating hours of a time/cycle limit.

Figure 5 Survey Module QA

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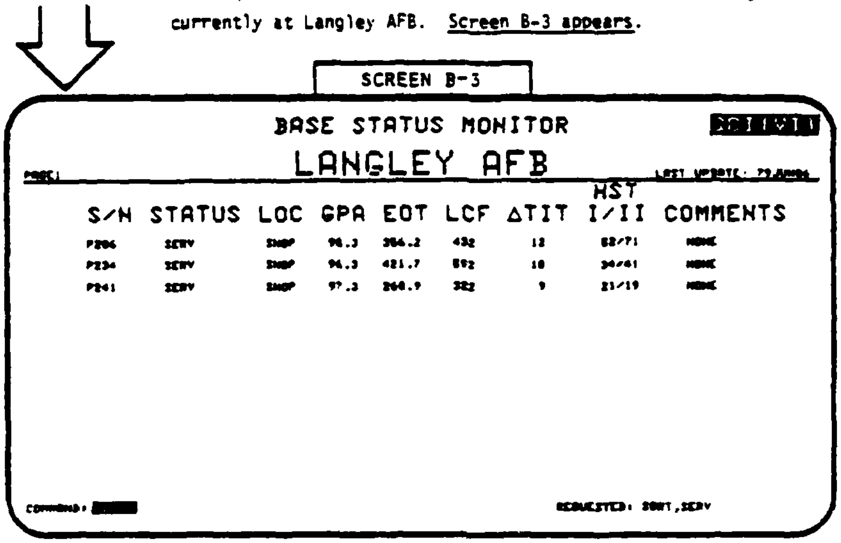
DISPLAY SYSTEM B (CONTINUED)

You request the AMS to indicate the serviceable spare engines currently at Langley AFB. Screen B-3 appears.



STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen B-1 is a base status summary. Its purpose is to provide you with the information to make a quick assessment of the base's status. Rate the information content of screen B-1.

   too much ________ : ________ : ________ enough : ________ : ________ too little

2. Is there any information you would eliminate from screen B-1? If so, mark through it directly on the screen.

3. Is there any information that could have been added to increase the effectiveness and clarity of screen B-1? If so, write these additional items on the screen.

4. Screen B-2 contains information on each engine's health rating (GPA), operating time, cycle counts, trim adjustment, hot section time, and time/cycle removals within the next 100 operating hours. Is there any column that you could eliminate? If so, draw through that column.

5. Please comment on Display System B:

   ____

   ____

   ____

Figure 6 Survey Module QA

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Display Formulation:

The bare base deployment scenario is accompanied by display systems A and B (Figure 3, 4, 5, 6). Each system contains three screens of information. Table 6 summarizes display density, format and special techniques.

Table 6
Module QA Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density; Tabular	Low Density; Tabular
SCREEN 2	Medium Density; Tabular; Inverse Video	High Density; Tabular
SCREEN 3	Medium Density; Tabular	High Density; Tabular

Analysis:

The base status summary (Screen 1) is a key display. Its purpose is to provide base level personnel with a quick assessment of the base's status. The survey evaluates the content and organization of the information necessary to make this assessment. The survey participant is required to rate the information content and eliminate unnecessary data or add any items that would increase display effectiveness and clarity.

Whenever a user sorts or ranks his engine files on an attribute (e.g. serviceable status, joint GPA) he obtains a fixed set of information for each engine. This would include the engine or aircraft serial number, status, location, and summary information such as GPA, operating time, cycles, etc. By evaluating the densities of data on the two display systems, the participant identifies which items to include in the fixed index display set. The participant also indicates preferences for presenting HST and Life Limits in alternative formats. GPA was used as the ranking factor for the deployment scenario. The participant is asked to rank the effectiveness of using GPA for identifying the aircraft with the best performing engines.

3.4 QB-Pilot Squawk

Scenario:

In two recent sorties, the pilot squawked staggered throttles and low performance for engine 119L (P106). After conferring with the Chief of the Propulsion Branch, the engine was pulled and run across the test stand. The test stand technician reports low speed, high fuel consumption and high temperature. As Branch Chief, you must use the automated engine management system to isolate the reason for low performance to the module level and recommend disposition of the problem.

Scenario Objective:

This scenario is used to test the engine profile function and subsystem displays to identify and isolate the cause for low engine performance to the modular level. Displays are formulated to identify the information (e.g., GPA rating, time, cycles, HST (I/II), etc.) that will appear on the profile. Subsystem displays address the health of the individual engine modules.

Display Formulation:

The Pilot Squawk scenario is accompanied by two display systems (Figure 7, 8, 9, 10). Each display system contains two screens of data. Table 7 summarizes display density, format, and special techniques.

Table 7
Module QB Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	Low Density; Tabular; Inverse Video	High Density; Tabular; Inverse Video
SCREEN 2	Low Density; Tabular; Inverse Video	High Density; Graphical; Historical Trend

Analysis:

The engine profile contains summary statistics and diagnostic information. The survey participant evaluates the content and format of the items that should be included in this ½ screen display. Questions specifically address the approach of displaying certain engine information on exception only (i.e. when a particular problem exists).

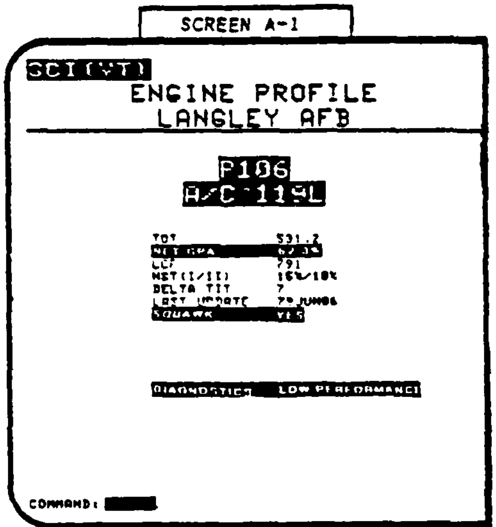
The subsystem displays present information on modular health. The participant rates the effectiveness of graphical vs tabular information and the utility of trended GPA.

The participant evaluates the utilization of inverse video to highlight messages on the display screen. He also can indicate a preference for presenting HST in alternative formats.

DISPLAY SYSTEM A

You request the AMS to provide the profile on P106. The engine profile (screen A-1) appears on the left half of your video terminal. It contains summary statistics and diagnostic information.

SCREEN A-1



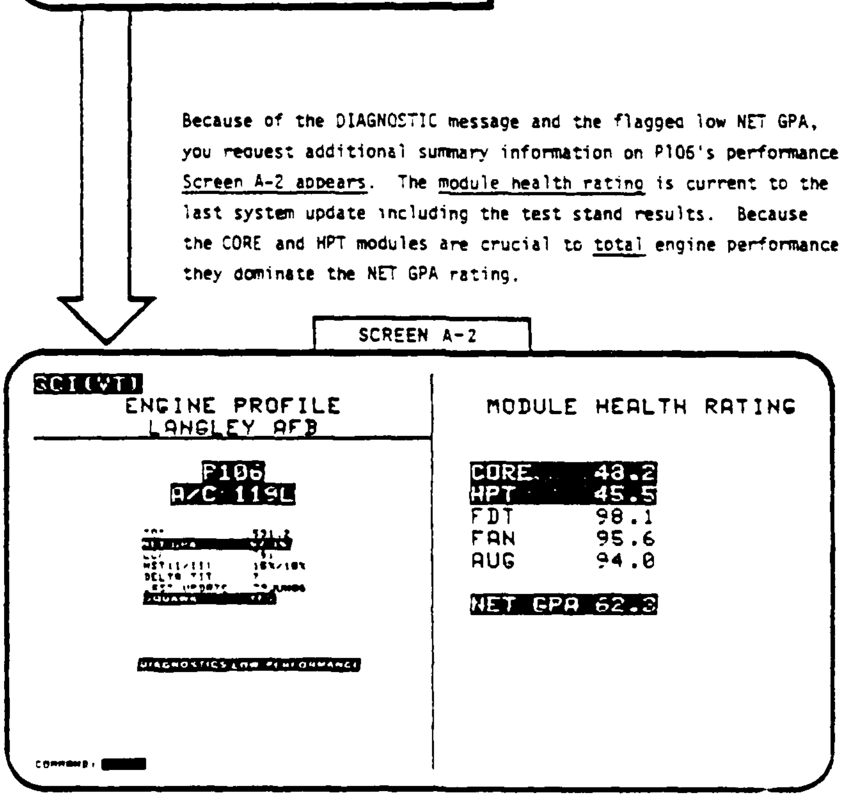
P106's aircraft tail number is indicated.

NET GPA is the overall health rating for the engine. It measures operating performance relative to a new unit.

Hot section time (HST) is shown as a % of total operating time.

Because of the DIAGNOSTIC message and the flagged low NET GPA, you request additional summary information on P106's performance. Screen A-2 appears. The module health rating is current to the last system update including the test stand results. Because the CORE and HPT modules are crucial to total engine performance, they dominate the NET GPA rating.

SCREEN A-2



The low health ratings, on the CORE and HPT indicate that they require maintenance.

Figure 7 Survey Module QB

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. The purpose of the engine profile (screen A-1) is to provide summary statistics and diagnostic information on the engine. Is there any other summary information you would require? If so, write it on screen A-1.

2. Messages have been highlighted to attract your attention. Rate the effectiveness of this technique.

   very effective _____ : _____ : _____ : _____ : _____ ineffective

3. Would you prefer Hot Section Time displayed in operating hours or as percent of EOT?

   _____ hours   _____ percent

4. Comment on Display System A:

   ____
   ____
   ____

Figure 8 Survey Module QB

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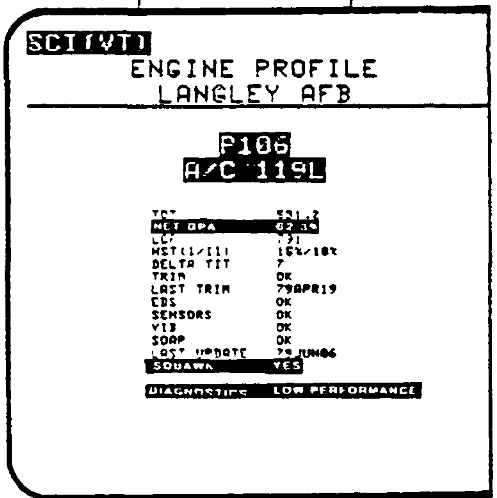
DISPLAY SYSTEM B

You request the AMS to provide the profile on P106. The engine profile (screen B-1) appears on the left half of your video terminal. It contains summary statistics and diagnostic information.

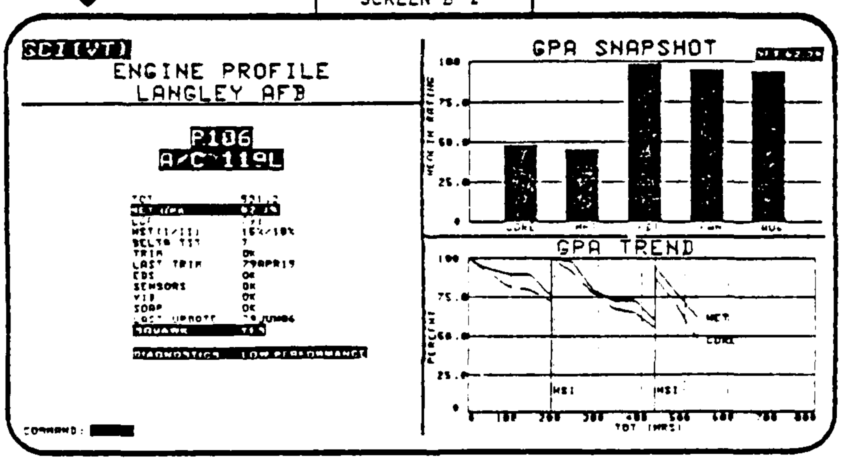
SCREEN B-1



The OK status means that the engine diagnostics system (EDS) and on-board sensors are operating normally and that the vibration and oil analysis reports are within specified limits.

Because of the DIAGNOSTIC message and the flagged low NET GPA, you request additional summary information on P106's performance. Screen B-2 appears. The module health rating is current to the last system update including the test stand results. Because the CORE and HPT modules are crucial to total engine performance, they dominate the NET GPA rating.

SCREEN B-2



GPA TREND plots GPA versus total operating time (TOT) for the overall engine and the core module. The graph shows the effect of two hot section maintenance actions on engine core health rating.

Figure 9 Survey Module QB PROCEED TO NEXT PAGE

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. On screen B-1 OK status is listed for a number of categories (for example, EDS and SENSORS). Should this information be displayed only when a problem exists?

   _____ yes   _____ no

2. Rate the effectiveness of the bar graph used to show the module health ratings in the GPA SNAPSHOT.

   very effective _______ : _______ : _______ : _______ : _______ ineffective

3. Rate the effectiveness of historical information provided by the GPA TREND.

   very helpful _______ : _______ : _______ : _______ : _______ useless

   _______ I don't understand it

4. Comment on Display System B.

   ____

   ____

   ____

Figure 10 Survey Module QB

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3.5 QC-Engine Alarm

Scenario:

You are the Chief of the Propulsion Branch at Luke AFB. Late yesterday, a member of the Aircraft Generation Squadron reported an aircraft (A/C 129) with an off-idle stall. Because the night shift was shorthanded, trouble-shooting was delayed. Last night the automated management system (AMS) was updated with flight acquired performance information from the engine diagnostic system. As Propulsion Branch Chief, you will use the AMS to identify the reason for the off-idle stall and direct the maintenance activity (e.g. replace sensor, borescope compressor, pull engine, etc.).

Scenario Objective:

The purpose of this scenario is to illustrate the alarm function of the engine monitoring system. The faulted engine is identified on a grouped display such as a base status listing. The user then references a profile summary that supplies him with relevant diagnostic data. The displays allow him to evaluate candidate faults such as RCVV off-schedule, actuator failure, or TT25 sensor failure.

Display Formulation:

The engine alarm scenario has display system A and B (Figures 11, 12, 13, 14). Each system contains two screens of information. Table 8 summarizes display density, format, and special techniques.

Table 8
Module QC Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density; Tabular; Inverse Video	Low Density; Tabular; Inverse Video
SCREEN 2	Low Density; Tabular; Inverse Video	High Density; Tabular Inverse Video

Analysis:

The base status summary is a key display. Its purpose is to provide base personnel with the information to make a quick assessment of the base's status. Alarm information is provided via inverse video. The survey evaluates the content and organization of the information necessary to make the status assessment and identify the alarm. The participant in required to rate the information content and eliminate unnecessary data or add any items that would increase the displays effectiveness and clarity.

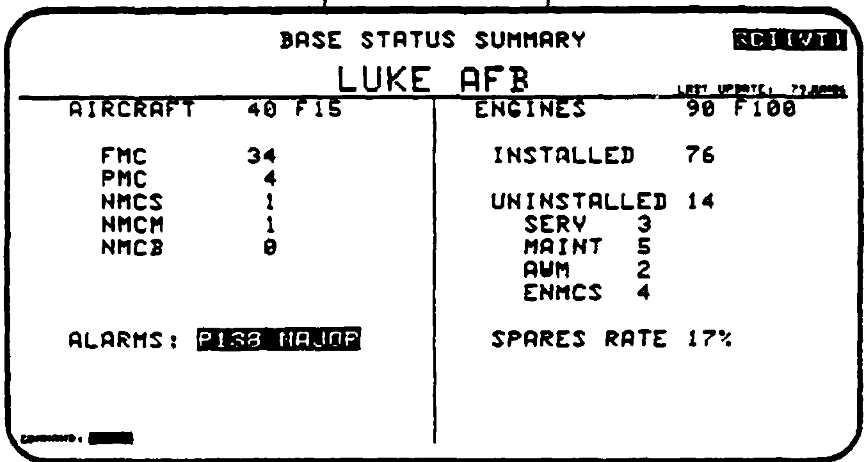
The engine profile contains summary statistics and diagnostic information on the engine with the major alarm. The participant evaluates the content and format of the items that should be included in this ½ screen display. He also rates the adequacy of the diagnostic information relative to specifing maintenance on the faulted engine. Questions are directed towards the utilization of inverse video representations and the display of certain information on an exception basis.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide an updated report on Luke's status. The base status summary (screen A-1) appears. The purpose of screen A-1 is to indicate the status of the aircraft and engines assigned to your base. Based on updated performance data, the AMS reports an ALARM on P138.

SCREEN A-1

AIRCRAFT are classified according to mission capability.

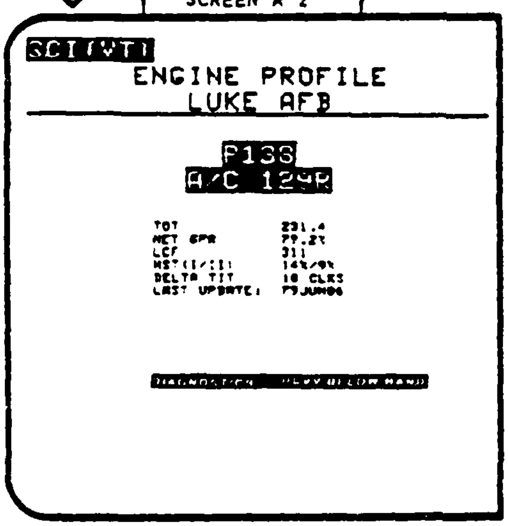


Uninstalled engines are identified according to repair status.

SPARES RATE is % of uninstalled to installed engines.

You request the profile of the engine with the major alarm (P138). The engine profile (screen A-2) appears on the left half of your video terminal. It shows summary statistics and diagnostic information.

SCREEN A-2



P138's aircraft tail number is indicated.

NET GPA is the health rating for the entire engine.

Hot section time (HST) at temperature levels I and II is given as a percentage of the total operating time.

The engine's trim status (DELTA TIT) has 10 click positions remaining.

DIAGNOSTIC information indicates that the PCVV is below the trim band and is a probable cause of the off-idle stall. The DIAGNOSTIC message is based on the current engine performance data.

Figure 11 Survey Module QC

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen A-1 is a base status summary. Its purpose is to provide you with the information to make a quick assessment of the base's status. Rate the information content of screen A-1.

   too much ________ : ________ : ________ : ________ : ________ too little
   (middle: enough)

2. Is there any information you would eliminate from A-1? If so, mark through it directly on the screen.

3. Is there any information you would have added to increase the effectiveness and clarity of screen A-1? If so, write these additional items on the screen.

4. The ALARM and DIAGNOSTIC messages for engine P138 were highlighted to attract your attention. How effective was this technique?

   very effective ________ : ________ : ________ : ________ : ________ ineffective

5. The engine profile (screen A-2) provides summary statistics and diagnostic information. Is there any additional information that could have been added to the profile to increase its effectiveness? If so, write these additional items on screen A-2.

6. Would you prefer Hot Section Time displayed in operating hours or as a percentage of EOT?

   ______ hours ______ percent

7. Is the diagnostic information that is provided adequate for making your maintenance decision?

   ______ yes ______ no

8. Comment on Display System A:

   ____

   ____

   ____

Figure 12 Survey Module QC

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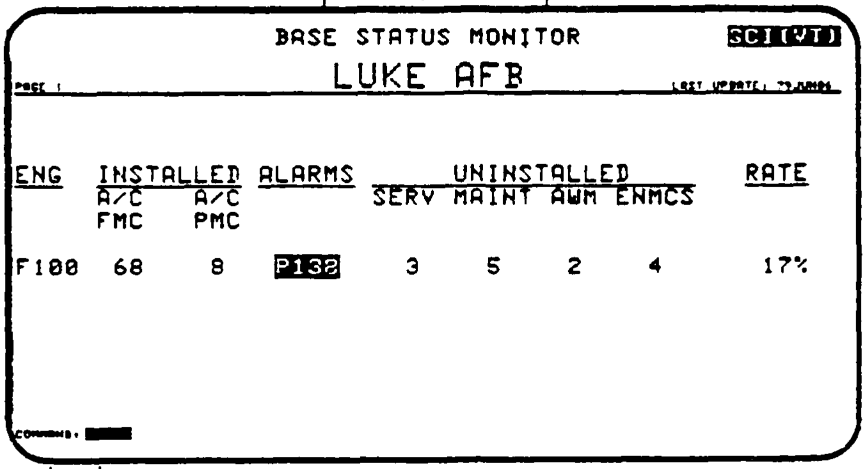
DISPLAY SYSTEM B

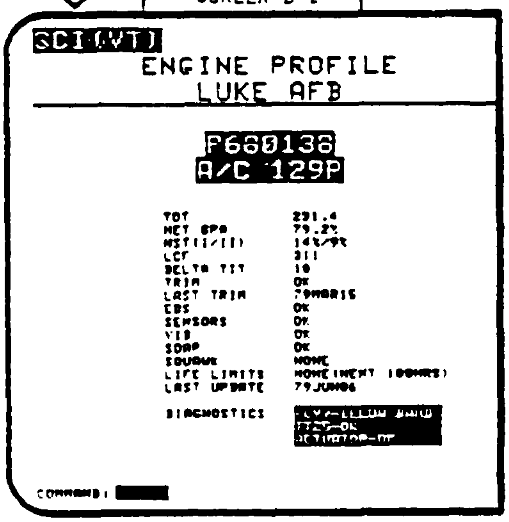
You request your AMS to provide an updated report on Luke's status. Screen B-1 appears. It shows engine status and location. Based on updated performance data, the AMS reports an ALARM on P138.

SCREEN B-1



You request the profile of P138. The engine profile (screen B-2) appears on half of your video terminal. It contains summary statistics and diagnostic information.

SCREEN B-2



The OK status means that the engine diagnostic system and on-board sensors are operating within tolerances and that the vibration and oil analysis reports are within specified limits.

The DIAGNOSTIC message provides information on three possible reasons for off-idle stall. RCVV's below trim band is given as the most probable cause.

Figure 13 Survey Module QC

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen B-1 is a base status summary. Its purpose is to provide you with the information to make a quick assessment of the base's status. Rate the information content of screen B-1.

   too much ________ : ________ : ________ (enough) : ________ : ________ too little

2. Is there any information you would eliminate from B-1? If so, mark through it directly on the screen.

3. Is there any information you would have added to increase the effectiveness and clarity of screen B-1? If so, write these additional items on the screen.

4. On screen B-2 the OK status is listed for a number of categories (for example, EDS and SENSORS). Should this information be displayed only when a problem exists?

   ______ yes ______ no

5. DELTA TIT is the engine's trim status. It is measured in click positions (control adjustment racnets) remaining. How essential is this information?

   extremely essential ________ : ________ : ________ : ________ : ________ worthless

   ________ I don't know

6. Is the diagnostic information that is provided adequate for making your maintenance decision?

   complete ________ : ________ : ________ : ________ : ________ exceptionally deficient

7. Comment on Display System B:

   ____

   ____

   ____

Figure 14 Survey Module QC

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3.6 D-TCTO Management

Scenario:

As Chief of Propulsion at Luke AFB, you have received notification of TCTO 2J-F100-545 for modification of the engine electronic control (EEC) to incorporate a modified speed trim adjustment. You have been informed by supply that they have received the seven modification kits that Luke AFB requested three months ago after receiving the ECP. The TCTO applies to engine serial numbers P108 through P120, and P124 through P130. Which of these engines are assigned to Luke? What is their status (i.e., tail number, serviceable spares, maintenance shop, etc.)?

Scenario Objective:

Satisfying the requirements of time compliance technical orders has been identified as a driver for a large portion of the maintenance activity. The scenario illustrates the function of sorting engine files on the serial number attribute. By requesting the AMS to sort the base engine files, the user can access information (e.g. status, location, time, GPA, cycles, etc.) on each of engines at Luke.

Display Formulation:

The TCTO management scenario is accompanied by display systems A, B, and C, (Figure 15, 16, and 17). Each system contains one screen of information. Table 9 summarizes display density, format, and special techniques.

Table 9
Module QD Display Formulation

	SYSTEM A	SYSTEM B	SYSTEM C
SCREEN 1	High Density; Tabular; Inverse Video	Medium Density; Tabular/Graphical	Low Density; Tabular; Additional Sort

Analysis:

Whenever a user sorts his engine files on serial numbers he obtains a fixed set of information for each engine assigned to his base. This would include the engine serial number (i.e. sorting attribute), status, location and summary information such as GPA, operating time, cycles, etc.. By evaluating the varying densities of data on the three display systems the participant identifies which items to include in the fixed index display set. HST and Life Limited information can be represented in alternative formats. Participants are requested to indicate the preferable format.

Systems A and C are used to evaluate two techniques (inverse video and an additional sort) that allow for a quick differentiation between installed and uninstalled engines.

DISPLAY SYSTEM A

You request the automated management system (AMS) to indicate which of the engines are assigned to Luke AFB. Screen A-1 appears on your video terminal. The engines are listed by serial number. Uninstalled engines are highlighted. Location, GPA, operating cycle counts, and trim status (ΔTIT in clicks remaining) are given for each engine. Hot section time (HST) is given as a % of operating time.

SCREEN A-1

For installed engines, STATUS is the aircraft's mission capability. For uninstalled engines, it is the repair status.

BASE STATUS MONITOR SCI(VT)

LUKE AFB

POC: LAST UPDATE: 79 [illegible]

F100 S/N	STATUS	LOC	GPA	EOT	LCF	ΔTIT	HST I/II	COMMENTS
P100	FMC	1229	94.3	432.7	562	12	10%/12%	NONE
[illegible]	[illegible]	[illegible]	99.6	321.7	491	13	13%/15%	NONE
P113	FMC	125L	88.3	419.5	601	10	5%/6%	NONE
[illegible]	[illegible]	[illegible]	51.1	848.1	621	4	13%/15%	NONE
[illegible]	[illegible]	[illegible]	48.2	332.1	416	5	3%/3%	GEARBOX-33 HRS
P126	FMC-AVIONICS	1329	79.9	658.2	864	7	10%/6%	900 CYCLE CORE-63 HR
[illegible]	[illegible]	[illegible]	43.1	313.6	421	2	13%/15%	FUEL PUMP-75 HRS

COMMAND:

REQUESTED: SORT,S/N,100/120,124/130

COMMENT column is used to indicate components within 100 operating hours of time/cycle limits.

The system request is repeated for reference.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen A-1 contains information on each engine's current location, operating time, cycles, trim status, hot section time, and time/cycle removals within the next 100 operating hours. Is there any column you could eliminate? If so, draw through that column on the screen.

2. Would you prefer hot section time (HST) displayed in hours or as a percentage of EOT?

   ______ hours ______ percent

3. Uninstalled engines are highlighted on screen A-1 for the user's convenience. How effective is this technique?

   very effective: ______ : ______ : ______ : ______ : ______ ineffective

4. Comment on Display System A:

   ____

   ____

   ____

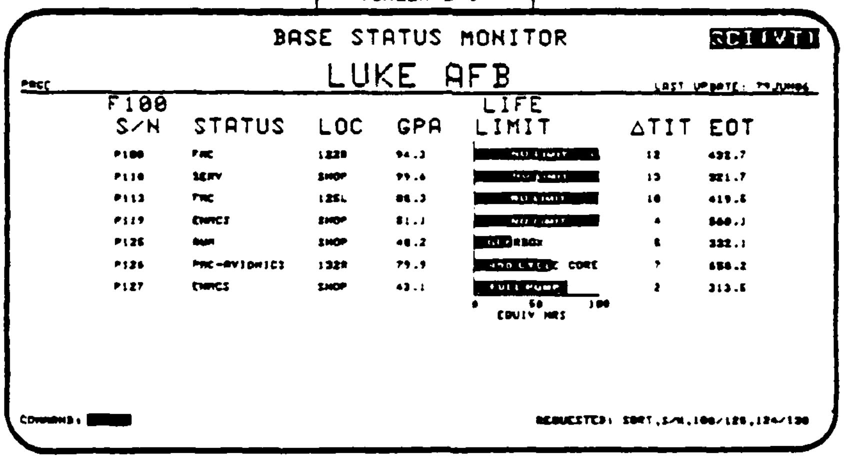
Figure 15 Survey Module QD

PROCEED TO NEXT PAGE

DISPLAY SYSTEM B

You request the AMS to indicate which of the engines are assigned to Luke AFB. Screen B-1 appears on your video terminal. The engines are listed by serial number. Status, location, GPA, trim adjustment, and operating time are given for each engine. LIFE LIMITS within the next 100 operating hours are represented on a bar graph.

SCREEN B-1



The system request is repeated for reference.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen B-1 contains information on each engine's current location, health, trim status, operating time, and time/cycle removals within the next 100 operating hours. Is there any column you would eliminate? If so, draw through that column on your screen.

3. Screen B-1 uses a bar graph to display information on components that will reach time/cycle limits within the next 100 operating hours. Rate the clarity of the bar graph representation of LIFE LIMITS.

   very clear ________ : ________ : ________ : ________ : ________ obscure

4. Comment on Display System B:

   ____

   ____

   ____

Figure 16 Survey Module QD

PROCEED TO NEXT PAGE

DISPLAY SYSTEM C

You request the AMS to indicate which of the engines are assigned to Luke AFB. Screen C-1 appears on your video terminal. Engines are listed by serial number in installed and uninstalled categories. Status, location, GPA, trim adjustment and LIFE LIMITS within 100 operating hours are given for each engine.

SCREEN C-1

BASE STATUS MONITOR

LUKE AFB

PAGE 1 LAST UPDATE 29JUN86

INSTALLED

S/N	STATUS	LOC	GPA	LIFE LIMITS	ΔTIT
P100	FMC	122R	94.3	NO LIMITS	12
P113	FMC	125L	88.3	NO LIMITS	10
P126	PMC-AVIONICS	132R	79.9	900 CYCLE CORE-63 HRS	7

UNINSTALLED

S/N	STATUS	LOC	GPA	LIFE LIMITS	ΔTIT
P118	SERV	SHOP	99.6	NO LIMITS	13
P119	ENMCS	SHOP	81.1	NO LIMITS	4
P125	AWP	SHOP	48.2	GEARBOX-33 HRS	5
P127	ENMCS	SHOP	43.1	FUEL PUMP-75 HRS	2

COMMAND: F100 REQUESTED: SORT,S/N,100/120,124/130

The system request is repeated for reference.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen C-1 contains information on each engine's current location, health, trim status, and time/cycle removals within the next 100 operating hours. Is there any column you would eliminate? If so, draw through the column on your screen.

2. Is there any additional engine information that you would require? If so, write these items on screen C-1.

3. The AMS automatically sorts the installed and uninstalled engines. How beneficial is this sorting process?

   extremely beneficial ________ : ________ : ________ : ________ : ________ worthless

4. Component LIFE LIMITS are displayed only if they occur within the next 100 operating hours. What do you prefer?

   _____ The 100-hour cutoff used in C-1

   _____ Another hour cutoff (specify: __________)

   _____ The component closest to its life limits regardless of the time/cycles remaining.

5. Comment on Display System C:

   ____

   ____

   ____

Figure 17 Survey Module QD

PROCEED TO NEXT PAGE

3.7 QE-Squadron GPA Degration

Scenario:

Squadron 119 at Luke AFB reports that its 18 F15 aircraft have experienced severe performance degradation in the last seven weeks. This situation could potentially result in a greater-than-average rate of engine removals. As maintenance officer, you suspect the special combat mission that the squadron has been flying since 19 April 1979 may have contributed to the degradation. 119 is the first squadron to fly this particular mission. As maintenance officer, you would like to compare the current "health" of the squadron's engines to their "health" when the mission began.

Scenario Objective:

This scenario illustrates sorting engine files on squadron. Performance information via GPA is displayed for each engine and selected modules. Various approaches to the presentation of derived engine performance variables are addressed.

Display Formulation:

The squadron GPA degradation scenario is accompanied by display system A and B, (Figure 18, 19, and 20). System A contains two screens of information, while system B contains one screen. Table 10 summarizes display density, format, and special techniques.

Table 10
Module QE Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density; Tabular; Snapshot	Medium Density Graphical Trended
SCREEN 2	High Density; Tabular; Snapshot	

Analysis:

The survey participant examines tabular and graphical alternatives for displaying performance/health information for the engines operated by Squadron 119. He evaluates his ability to establish the trends in engine and modular health from the tabular data. He rates the effectivenss of plotting GPA bar graphs for the current date and 19 April 1979 on the same graph. This technique allows the user to quickly establish the trend in engine and core health. The questions introduce the concept of trending engine health and correlating the trend to a specific engine operating mission.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide a snapshot of current GPA factors for Squadron 119. Screen A-1 appears on the left half of your video terminal. NET GPA measures the performance of the overall engine. It rates performance relative to a new unit.

SCREEN A-1

BASE STATUS MONITOR SCI (VT)

LUKE AFB

PAGE 1 LAST UPDATE: 79JUN06

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79 JUN 06

- GPA FACTOR -

RANGE	NET	CORE	HPT	FAN
90-100	3	2	3	15
80- 89	4	2	5	10
70- 79	6	6	7	7
60- 69	9	9	8	4
50- 59	8	10	9	0
40- 49	6	7	4	0
TOTAL	36			

COMMAND:

The NET column lists the number of engines in each NET GPA range for all engines in Squadron 119.

The CORE, HPT, and FAN columns list the number of engines with modular GPA factors in each range.

You now request the AMS to provide the GPA SNAPSHOT for 19 April 1979, so that you can compare it to the current distribution. This information appears on the right side of your video terminal (screen A-2).

SCREEN A-2

BASE STATUS MONITOR SCI (VT)

LUKE AFB

PAGE 1 LAST UPDATE: 79JUN06

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79 JUN 06

- GPA FACTOR -

RANGE	NET	CORE	HPT	FAN
90-100	3	2	3	15
80- 89	4	2	5	10
70- 79	6	6	7	7
60- 69	9	9	8	4
50- 59	8	10	9	0
40- 49	6	7	4	0
TOTAL	36			

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79 APR 19

RANGE	NET	CORE	HPT	FAN
90-100	18	16	17	30
80- 89	16	17	17	6
70- 79	2	3	2	0
60- 69	0	0	0	0
50- 59	0	0	0	0
40- 49	0	0	0	0
TOTAL	36			

COMMAND:

Figure 18 Survey Module QE

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. What is the general trend in GPA (health rating) for Squadron 119 from 19 April 1979 to 06 June 1979?

	UP	DOWN
NET Engine	____	____
CORE Module	____	____
HPT Module	____	____
FAN Module	____	____

2. Evaluate how you were able to establish the trend in engine and module health.

very quickly ____ : ____ : ____ : ____ : ____ very slowly

very easily ____ : ____ : ____ : ____ : ____ with great difficulty

3. Comment on Display System A:

____

____

____

Figure 19 Survey Module QE

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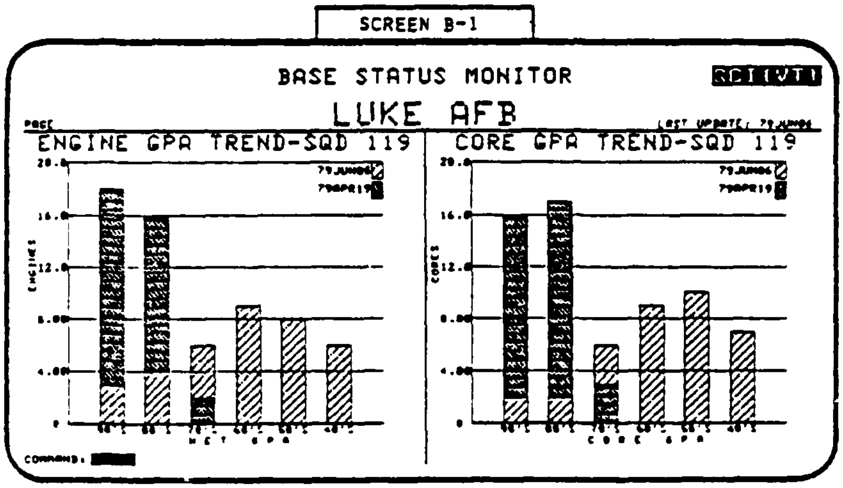
DISPLAY SYSTEM B

You request your AMS to provide a trend of engine health (GPA) for the current date and 19 April 1979. You specify that you want the NET GPA trend and the CORE GPA trend for Squadron 119. System B-1 appears on your video terminal.



The bar graphs for each date appear over each other. The trend is toward lower ENGINE and CORE GPA ratings at the later date indicating reduced squadron capability.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Rate the clarity of plotting the engine health (GPA) bar graphs for the current date and 19 April 1979 on the same graph.

   very clear ______ : ______ : ______ : ______ : ______ obscure

   ______ I don't understand it

2. Screen A-2 also includes the health information on the CORE modules in Squadron 119. What other modules, if any, would you want displayed?

   Other modules: ____________________

   Is the CORE module health necessary? ____ No ____ Yes

3. Comment on Display System B:

   ____

   ____

   ____

Figure 20 Survey Module QE

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3.8 QF- Base Maintenance Forecast

Scenario:

As Chief of the Propulsion Branch at Myrtle Beach AFB, you would like an indication of the engine removals expected on a monthly basis. Performance and time data are collected and monitored via the A-10 Turbine Engine Monitoring System (TEMS). A trending algorithm is used to predict forced removals (time/cycle limits) and removals for cause (failure). You can access this information via displays on your automated management system (AMS).

Scenario Objective:

This scenario introduces the concept of forecasting engine removals based on operating hours and current engine performance. The user is provided information for two categories; predicted removals driven by component time/cycle limits and predicted failures.

Display Formulation:

The base maintenance forecast scenario has display systems A and B, (Figure 21, 22, 23, and 24). Each system contains two screens of data. Table 11 summarizes display density, format, and special techniques.

Table 11
Module QF Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density, Tabular	High Density; Tabular
SCREEN 2	High Density; Tabular	Med. Density; Graphical

Analysis:

During the orientation visits, base maintenance personnel indicated a need for a tool to help forecast engine removals based on time/cycle limits and performance degradation. The survey participant is required to evaluate the information necessary to specify forced removals (e.g. estimated data, engine, aircraft tail # location, component driving the removals, and cycles or hours remaining). For the predicted failures, the user is requested to help identify the probability or confidence interval he would require placed on the forecast. The participant can also identify any additional information he would need on the engines scheduled to fail.

DISPLAY SYSTEM A

You request the automated management system (AMS) to provide a forecast of time/cycle removals. Screen A-1 appears on your video terminal. The forecast is based on accumulated operating hours (as of 06 June 1979) and Myrtle Beach AFB's flying profile. The forecast includes engine serial number, tail number location (LOC), estimated removal date (EST), and the hours/cycles remaining on the component forcing the engine removal.

SCREEN A-1

BASE STATUS MONITOR SCI(VT)

PAGE 1 MYRTLE BEACH AFB LAST UPDATE: 79JUN06

-TF34-

TIME/CYCLE REMOVALS

ENG	LOC	EST	BALANCE	COMPONENT
E300	204R	79JUN29	22.3H	1ST STAGE HPT BLADES
E204	211L	79JUL09	34.3H	1ST STAGE HPT BLADES
E124	113R	79JUL19	130 C	FAN DISK
E213	116R	79JUL22	162 C	1ST STAGE HPT COOLING PLATE
E241	178L	79JUL24	62 H	1ST STAGE HPT BLADES
E324	182L	79AUG11	179 C	1ST STAGE COMPRESSOR DISK
E319	109R	79AUG15	109 C	FAN DISK
E336	110R	79AUG22	91 H	1ST STAGE HPT BLADES
E111	137L	79AUG24	93 H	1ST STAGE HPT BLADES
E264	163L	79SEP07	222 C	FAN DISK
E333	232R	79SEP08	222 C	FAN DISK

MORE?

The removals are ordered in time. A simple terminal input to the AMS provides you with the next group.

You request the AMS for forecast removals due to engine failure or severe performance degradation. Screen A-2 appears. The forecast is based on the engine's current health (GPA) and the rate at which the engine's health is deteriorating.

SCREEN A-2

BASE STATUS MONITOR SCI(VT)

PAGE 1 MYRTLE BEACH AFB LAST UPDATE: 79JUN06

-TF34-

GPA PREDICTED FAILURE DATE (PROB>80%)

MONTH	ENG	LOC	GPA	EOT	GPA RATE
JULY 79	E143	121R	48.2	329.1	34 LAST 100 EOT
JULY 79	E205	132R	49.3	441.2	36 LAST 100 EOT
JULY 79	E230	112L	51.2	421.3	32 LAST 100 EOT
JULY 79	E224	201R	57.3	209.1	29 LAST 100 EOT
JULY 79	E201	119L	56.1	319.3	22 LAST 100 EOT
AUG 79	E119	121R	61.2	291.5	24 LAST 100 EOT
AUG 79	E127	129L	63.5	208.3	22 LAST 100 EOT
AUG 79	E112	100R	64.2	421.2	18 LAST 100 EOT
AUG 79	E249	172R	64.3	302.3	17 LAST 100 EOT
SEPT 79	E321	103L	67.1	201.3	15 LAST 100 EOT
SEPT 79	E161	142R	67.3	333.3	15 LAST 100 EOT
SEPT 79	E351	153L	68.3	229.3	14 LAST 100 EOT

MORE?

The removals are ordered in time. A simple terminal input to the AMS provides you with the next group.

GPA RATE is the % drop in the health factor over the last 100 engine operating hours (EOT).

Figure 21 Survey Module QF

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Is there additional information you would require on the engines forecast for time/cycle removals (screen A-1)? If so, write the items on the screen.

2. Is an 80% probability of failure accurate enough for base planning purposes?

   ______ yes ______ no

3. Is there any additional information you would require on the engines predicted to fail? If so, write the items on the screen.

4. How important to base maintenance planning would a good monthly forecast of engine removals be (both for failure and time/cycle limits):

   critical ________ : ________ : ________ : ________ : ________useless

5. Comment on Display System A:

   ____

   ____

   ____

Figure 22 Survey Module QF

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DISPLAY SYSTEM B

You request the AMS to provide a forecast of time/cycle removals. Screen B-1 appears on your video terminal. The forecast is based on accumulated operating hours (as of 06 June 1979) and Myrtle Beach AFB's flying profile.

SCREEN B-1

BASE STATUS MONITOR SCI(VT)

PAGE 1 MYRTLE BEACH AFB LAST UPDATE: 79JUN06

-TF34-

TIME/CYCLE REMOVALS

ENG	LOC	EST	BALANCE	COMPONENT
C306	204R	79JUN29	22.3H	1ST STAGE HPT BLADES
C204	211L	79JUL09	34.3H	1ST STAGE HPT BLADES
C124	113R	79JUL19	130 C	FAN DISK
C213	116R	79JUL22	152 C	1ST STAGE HPT COOLING PLATE
C241	170L	79JUL24	62 H	1ST STAGE HPT BLADES
C324	182L	79AUG11	179 C	1ST STAGE COMPRESSOR DISK
C319	189R	79AUG15	189 C	FAN DISK
C336	110R	79AUG22	91 H	1ST STAGE HPT BLADES
C111	137L	79AUG24	93 H	1ST STAGE HPT BLADES
C204	162L	79SEP07	222 C	FAN DISK
C333	232R	79SEP08	222 C	FAN DISK

MORE?

You request the AMS to forecast removals due to engine failure or severe performance degradation. Screen B-2 appears. It shows the number of engines in each 5-point GPA interval. The engines with a low NET GPA are more likely to fail if the prediction is made for the next three months.

SCREEN B-2

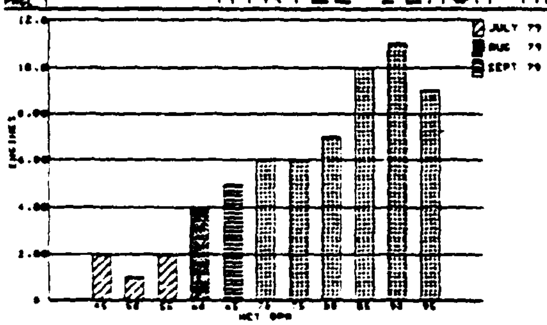
BASE STATUS MONITOR SCI(VT)

PAGE 1 MYRTLE BEACH AFB LAST UPDATE: 79JUN06

5 engines are predicted to fail in July.

4 engines in August.

5 engines in September.



ENG	LOC	GPA
C143	121R	48.2
C205	132R	49.3
C230	112L	51.2
C224	201R	57.3
C201	119L	58.1
C117	121R	61.2
C127	129L	63.5
C112	100R	64.2
C249	172R	64.3
C321	183L	67.1
C161	142R	67.3
C351	153L	68.3
C169	145R	68.5
C301	199L	68.9

The 14 engines with the lowest GPA factors are shown.

COMMAND:

Figure 23 Survey Module QF

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen B-2 uses a bar graph to represent the number of engines in each GPA interval. The engines with the lowest rating are more likely to fail and are indicated by the different bar graphs. Rate the effectiveness of this technique.

   very effective ______ : ______ : ______ : ______ : ______ ineffective

   ______ I don't understand it

2. Comment on Display System B:

   ____

   ____

   ____

Figure 24 Survey Module QF

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3.9 QG-On-Condition Maintenance Team

Scenario:

The On-Condition Maintenance (OCM) Team at San Antonio-ALC consists of the team chief, an engineer, a technician, and representatives from scheduling, production, and quality control. It is near the first of the month and SA-ALC has received an F100 engine (P106) from Luke AFB. Engine overtemp was the removal reason cited by base maintenance personnel. In addition, Luke flagged the engine for an abnormal SOAP report and high vibration on the gear box. As an OCM team member, you can access certain information on P106 via an automated management system (AMS).

Scenario:

The process of prescribing on-condition (or conditional) maintenance requires information contained in the engine profile and subsystem summaries. This scenario will be used to determine which portions of the base engine record must be transferred to the CDB when an engine/module is returned to the depot for repair. Candidate items for incorporation in the display include removal cause, diagnostic and performance information, balance of life on time/cycle limited components, SOAP, vibration plots and maintenance.

Display Formulation:

The OCM scenario is accompanied by display system A, which contains five screens of data, (Figure 25, 26, 27, and 28). Table 12 summarizes display density, format, and special techniques.

Table 12
Module QG Display Formulation

	SYSTEM A
SCREEN 1	High Density; Tabular; Inverse Video
SCREEN 2	High Density; Graphical; Trended Data
SCREEN 3	High Density; Graphical; Trended Data
SCREEN 4	High Density; Tabular/Graphical; Trended Data
SCREEN 5	Medium Density; Tabular

Analysis:

The engine profile provides summary statistics and diagnostic information on the engine that has been transferred from Luke. Highlighted messages direct the OCM team to request additional subsummary displays. The participant identifies the set of statistics he wants to appear on the profile and rates the effectiveness of the inverse video representation.

Two graphical modes are used to display engine/module health. The GPA snapshot provides a relative picture of current module health. The participant evaluates the effectiveness of the bar graph representation. Trended GPA history (for the overall engine and core) is plotted against total engine operating time. The effect of two hot section inspections on engine/core performance is illustrated. This helps to correlate the effect of maintenance and performance. The participant indicates the effectiveness of these displays.

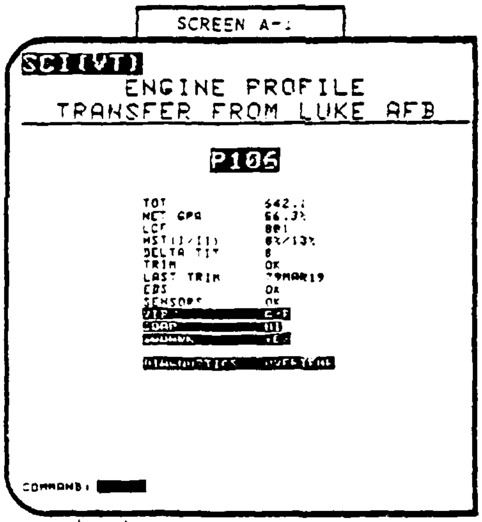
SOAP and recent vibration history are also available to the OCM team via display system A. The participant evaluates his requirements for this information and indicates the essentialness and effectiveness of the graphical displays.

Engine/module maintenance history is available from a number of sources (MMICS, AF forms 781E and 95). Screen A-4 presents an additional alternative for providing historical information and referencing it to engine operating and calendar time. The survey participant evaluates the utility of this method for displaying history.

The AMS provides a list of recommended opportunistic maintenance for time/cycle component replacements and TCTO's. The participant evaluates this display option relative to the information currently available for specifying opportunistic maintenance.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide the profile for P106. The engine profile (screen A-1) appears on the left side of your video terminal. It shows summary statistics and diagnostic information.



NET GPA is the overall health rating for the engine. It measures operating performance relative to a new unit.

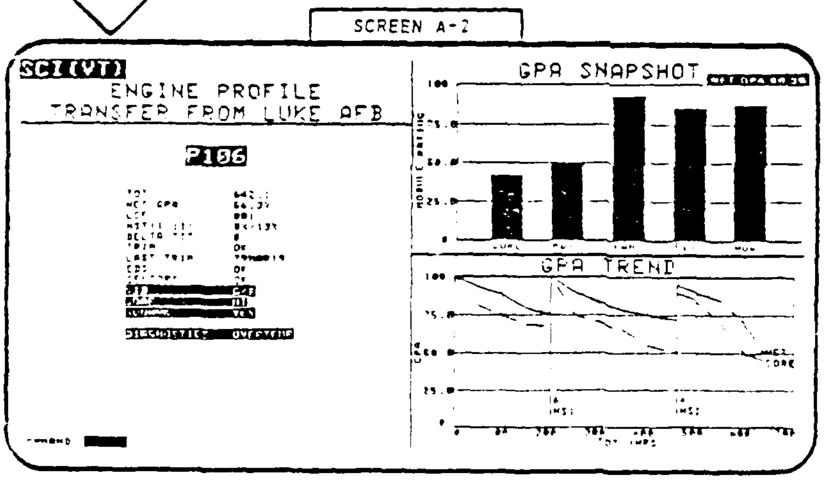
Hot section time (HST) is shown as a % of total operating time (TOT).

The OK status indicates that the diagnostic system (EDS) and on-board sensors are operating normally.

Vibration (VIB) message indicates the gearbox (G/B) is above the TO limit. The SOAP message indicates an abnormal increase in nickel (NI) particles in the oil sample.

DIAGNOSTIC message indicates an overtemp condition on the engine.

You first request additional information on P106's performance. Screen A-2 appears on the video terminal. Each module in the gas path has its own health rating. Because CORE and HPT modules are crucial to total engine performance, they dominate the NET GPA rating. A low health rating (<50%) indicates a module may require maintenance.



GPA SNAPSHOT shows the individual module health rating as of the last update.

GPA TREND plots GPA vs. total operating time (TOT) for the overall engine and the core module. The graph shows the effect of two hot section maintenance actions on engine core health ratings.

The numbers above the HSI indicate entries in the HISTORY (screen [illegible]).

Figure 25. Survey Module 06

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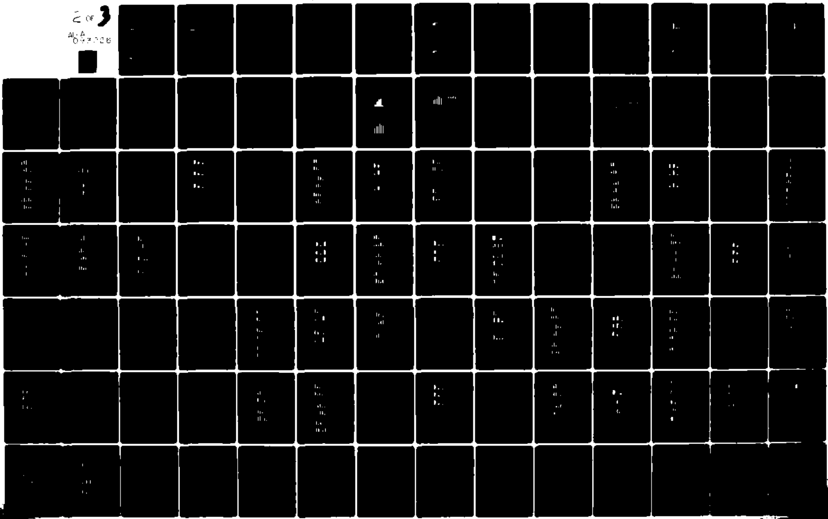
AD-A093 226 SYSTEMS CONTROL INC (VT) PALO ALTO CA F/G 21/5
TURBINE ENGINE FAULT DETECTION AND ISOLATION PROGRAM. PHASE I. --ETC(U)
APR 80 L E BAKER, R L DE HOFF, W E HALL
UNCLASSIFIED AFWAL-TR-80-2053-VOL-2 NL

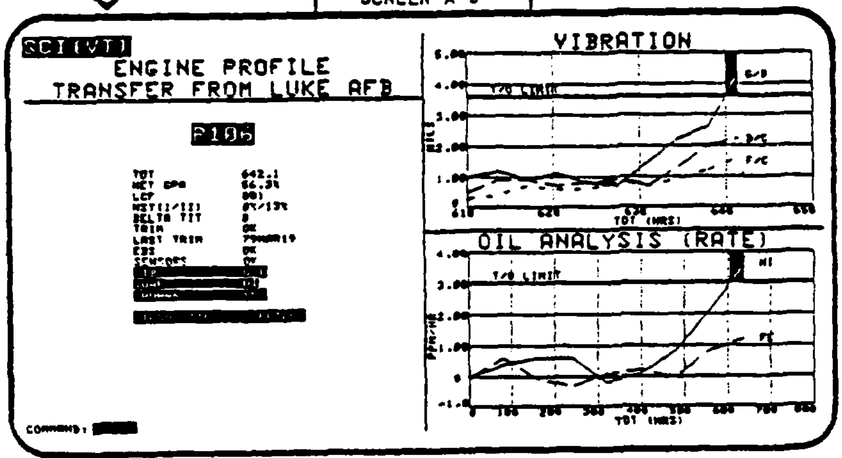
2 OF 3
AD A
093226



DISPLAY SYSTEM A (CONTINUED)

Because of the VIB and SOAP message you request recent vibration history and oil analysis for P106. Screen A-3 appears. Abnormalities are automatically highlighted on your video screen.

SCREEN A-3

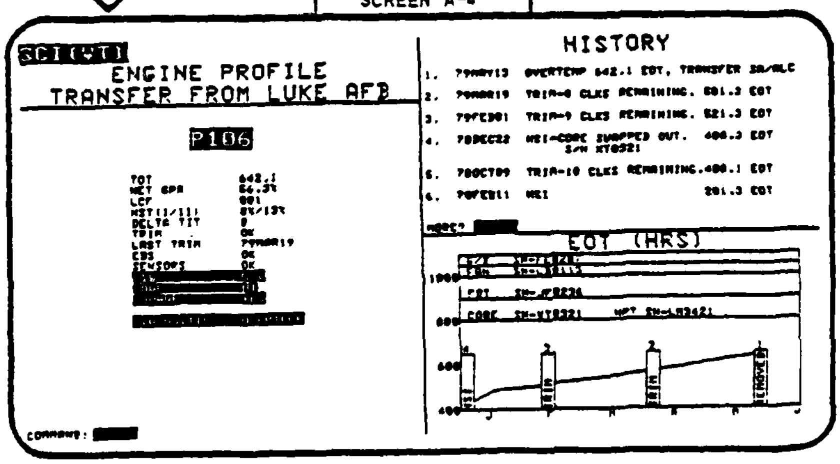


VIBRATION (measured in mils) is plotted over the last 42 operating hours for the gearbox (G/B), the diffuser case (D/C), and the fan case (F/C).

The calculated rate of change in nickel (NI) and iron (Fe) is plotted versus total operating time.

To assist in your assessment of P106, you request some recent maintenance history. Screen A-4 appears on your video terminal. The HISTORY report lists the six most recent maintenance events. By a simple terminal input you can display older history. Engine operating time (EOT) is plotted versus calendar months. The horizontal lines represent the operating hour when a module must be removed to replace a time/cycle limited component.

SCREEN A-4



The numbers above the maintenance action reference entries in the HISTORY.

Figure 26 Survey Module QG

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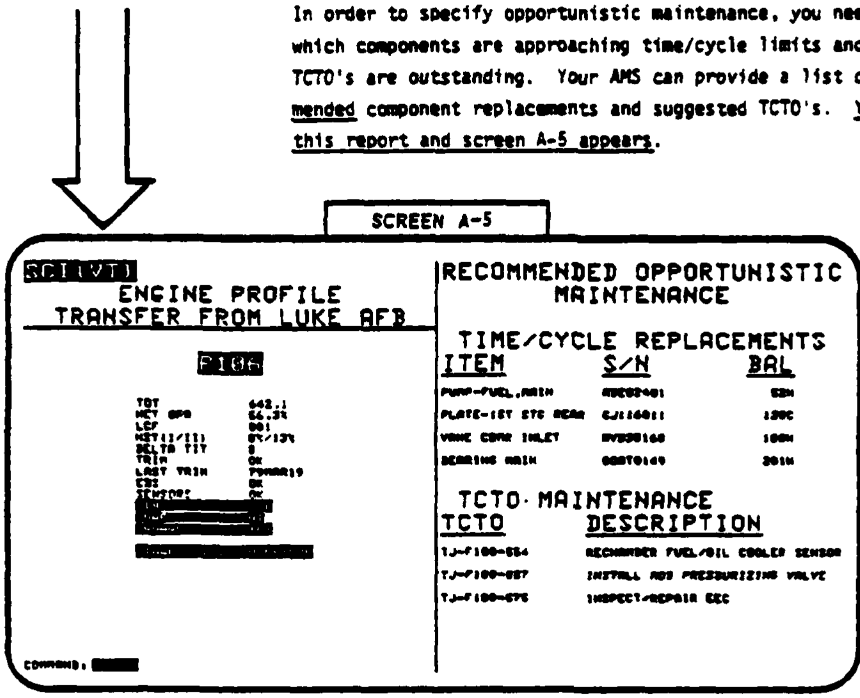
DISPLAY SYSTEM A (CONTINUED)

In order to specify opportunistic maintenance, you need to know which components are approaching time/cycle limits and which TCTO's are outstanding. Your AMS can provide a list of recommended component replacements and suggested TCTO's. You request this report and screen A-5 appears.



AMS shows component name, serial number (S/N), and remaining life (BAL) in hours and cycles.

AMS lists the TCTO number and a brief DESCRIPTION.

Figure 27 Survey Module QG

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. The purpose of the engine profile (screen A-1) is to provide summary information on the engine. Is there any other summary information you would require? If so, write it on screen A-1.

2. Messages on screen A-1 have been highlighted to attract your attention to engine problems and diagnostic information. Rate the effectiveness of this technique.

   very effective ______ : ______ : ______ : ______ : ______ ineffective

3. Rate the effectiveness of the bar graph used to show the module health ratings in the GPA SNAPSHOT (screen A-2).

   very effective ______ : ______ : ______ : ______ : ______ ineffective

4. Rate the effectiveness of the historical information provided by the GPA TREND (screen A-2).

   very helpful ______ : ______ : ______ : ______ : ______ useless

   ______ I don't understand it

5. Rate the benefits of displaying the recent vibration history for the gear box, the diffuser case, and the fan case.

   very helpful ______ : ______ : ______ : ______ : ______ useless

   ______ I don't understand it

6. Rate the desirability of including SOAP information on the OCM team.

   very essential ______ : ______ : ______ : ______ : ______ not required

7. The OIL ANALYSIS plot depicts particulate <u>rate of change</u> over engine operating hours rather than the particulate level. Evaluate the effectiveness of the OIL ANALYSIS graph (screen A-3) used to present the assay results.

   very effective ______ : ______ : ______ : ______ : ______ ineffective

   ______ I don't understand it

8. How effective is the maintenance HISTORY and engine operating time displayed on screen A-4?

   very effective ______ : ______ : ______ : ______ : ______ ineffective

   ______ I don't understand it

9. How would you prefer engine/maintenance history presented to the OCM:

   ______ As in screen A-4

   ______ Screen A-4 plus forms 781E and 95

   ______ MMICS TRE

   ______ Other (specify: ____________________________)

10. On screen A-5 the AMS displays the life limited components that it <u>recommends</u> for replacement. Would you prefer this recommendation or a complete listing of components with cycle/hour balances (G337.3017):

    ______ Recommended replacements as in screen A-5

    ______ G337.3017 listing

    ______ Other (specify: ____________________________)

11. Would you prefer the AMS to provide the entire list of outstanding TCTO's or to display only those TCTO's the AMS recommends for completion during this current repair:

    ______ Entire list of outstanding TCTO's

    ______ Recommended TCTO's only

    ______ Entire list of TCTO's with recommended ones highlighted.

Figure 28 Survey Module QG

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3.10 QH-Maintenance Forecast

Scenario:

You are the TF34 engine manager at San Antonio ALC. Engine performance data are collected and monitored via the A-10 Turbine Engine Monitoring System (TEMS). A trending algorithm is used to predict the engines expected for removal for depot level repair. You can access this information to determine how many TF34 engines SA-ALC can expect from Myrtle Beach AFB next month.

Scenario Objective:

This scenario introduces the concept of forecasting monthly engine removals and expected depot returns via an interactive routine. The engine manager supplies the base, the month, and the engine type and AMS provides removal information.

Display Formulation:

The maintenance forecast scenario is accompanied by one display system with two screens (Figure 29 and 30). The first screen illustrates an interactive input menu; the second screen provides the output. Table 13 summarizes display density, format, and special techniques.

Table 13
Module QH Display Formulation

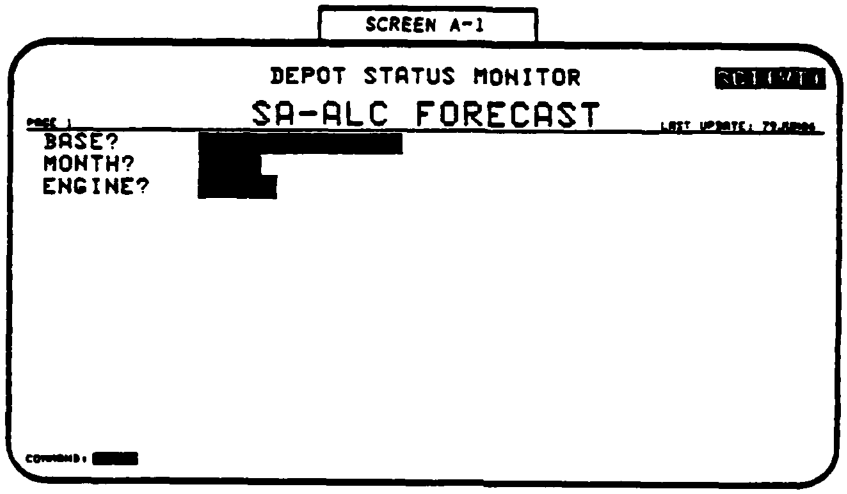
	SYSTEM A
SCREEN 1	Low Density; Tabular User Interactive
SCREEN 2	Low Density; Tabular

Analysis:

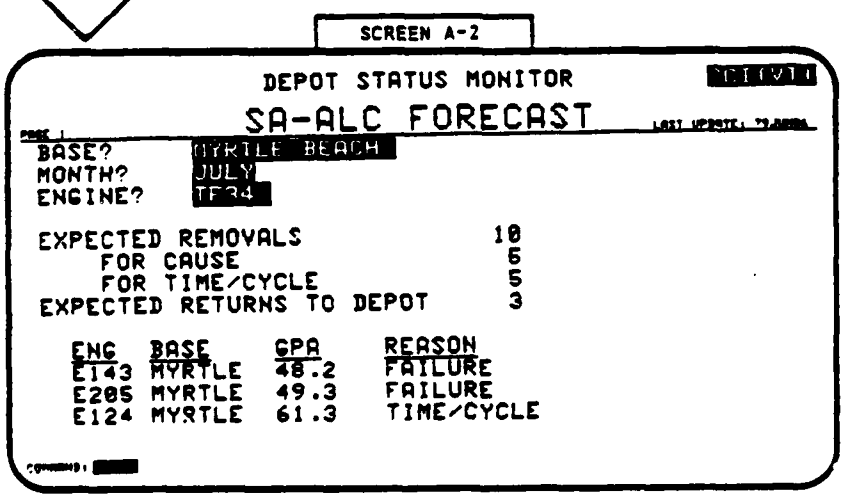
The ability to improve forecasts of engine removals (based on engine performance/health data) has been identified as a candidate benefit from automated TEMS. The survey evaluates the benefits of such a capability. The participant rates the management effectiveness of the display system and specifies the required accuracy. He also indicates any requirement for additional data on engines predicted for removal.

DISPLAY SYSTEM A

You request the automated management system to provide the SA-ALC FORECAST program. Screen A-1 appears on your video terminal. The forecast program is user-interactive. You must specify answers to the three questions that the AMS asks.



You type in the request for the prediction of TF34 engine removals at Myrtle Beach AFB for July. Screen A-2 appears. It lists the number of EXPECTED REMOVAL for failure (CAUSE) and operating limits (TIME/CYCLE). Three of the engines are likely to be returned to the depot. The engines are identified.



The low GPA rating indicates severe performance degradation and a high probability of engine failure.

Figure 29 Survey Module QH

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Rate the management effectiveness of a monthly forecast of expected engine removals and depot returns based on engine performance and health.

   extremely valuable ________ : ________ : ________ : ________ : ________ worthless

2. How much accuracy would you require of a forecast:

   _____ Correct more than 90% of the time

   _____ Correct more than 80% of the time

   _____ Correct more than 70% of the time

   _____ No opinion.

3. Screen A-2 provides serial number, health rating (GPA), and probable removal cause with each engine forecasted for return to the depot. Is there additional information you would like for the engines? If so, write these items onto the screen.

4. Comment on Display System A:

   ____

   ____

   ____

Figure 30 Survey Module QH

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3.11 QI-Multiple Base Deployment

Scenario:

TAC has received orders from HQUSAF to deploy 10 F15's and sufficient spare engines to a remote location for 14 days. You may choose engines from two bases (Luke and Langley) to support the deployment. Aircraft are scheduled to fly two sorties per day. On-site maintenance will be limited. You have one weeks lead time to plan for the deployment. Which aircraft and which spare engine should you deploy?

Scenario Objective:

The concept of an interactive routine to help plan command level deployments is addressed in the display systems that accompany this scenario. The proposed TAC deployment planner would question the user on various details of the deployment (e.g. duration, sortie rate, maintenance support, mission profile, etc.). Based on his requirements the user would be provided with the optimum combination of engines, aircraft and spares to support the deployment.

Display Formulation:

The multiple base deployment is accompanied by display system A and B, (figure 31, 32, 33, 34, and 35). Screen 1 and 2 for both systems illustrate the interactive input menu. System A has one output display and System B has two. Table 14 summarizes display density, format, and special techniques.

Table 14
Module QI Display Formulation

SCREEN 1	Medium Density; Tabular Menu	Medium Density; Tabular; Menu
SCREEN 2	Medium Density; Tabular User/Interactive	Medium Density; Tabular; User/ Interactive
SCREEN 3	Medium Density; Tabular Inverse Video	High Density; Tabular; Inverse Video
SCREEN 4		High Density; Tabular; Inverse Video

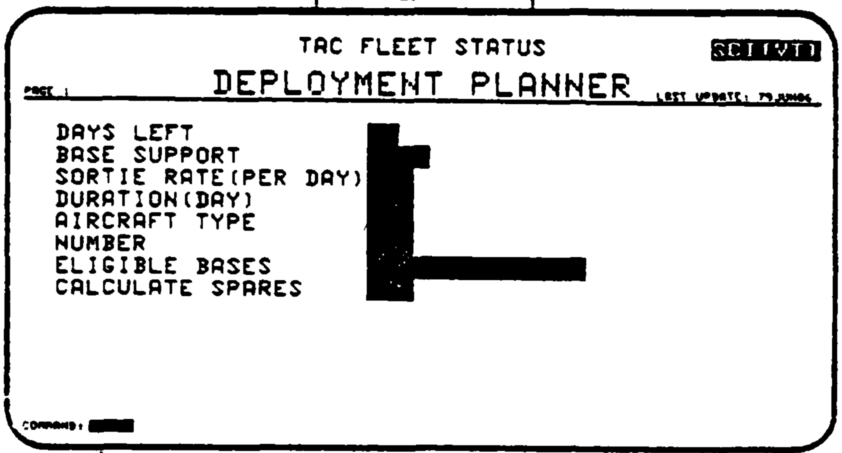
Analysis:

The survey evaluates the TAC Deployment Planner as a planning tool at the command level. The participant indicates any requirement for additional information on recommended engines and aircraft. The option of using the AMS to calculate spares requirements based on the deployment flying schedule and engine health is evaluated.

DISPLAY SYSTEM A

You request the automated management system (AMS) to provide the TACTICAL DEPLOYMENT PLANNER. Screen A-1 appears on your video terminal. The PLANNER is user-interactive. You must specify information concerning the deployment.

SCREEN A-1



DAYS LEFT is lead time.

BASE SUPPORT is degree of on-site maintenance. SORTIE RATES is the flying schedule. DURATION is the deployment length. The PLANNER is programmed to calculate the number of spares required to support the deployment specified.

You input the information that you have been provided by HQUSAF (screen A-2).

SCREEN A-2

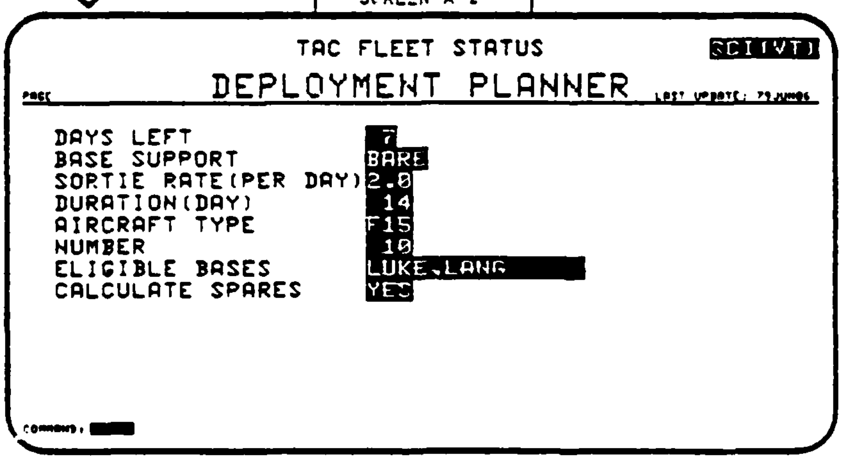


Figure 31 Survey Module QH

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DISPLAY SYSTEM A (CONTINUED)

The AMS PLANNER recommends the best aircraft to support the deployment (screen A-3). The engines installed in the aircraft have high health ratings. The AMS PLANNER recommends four spare engines and identifies their location.

SCREEN A-3

TAC FLEET STATUS

SCI(VT)

DEPLOYMENT PLANNER

High-lighted engine serial numbers (S/N) indicate you must install the spare.

AIRCRAFT

A/C	BASE	S/N L	S/N R
124	LUKE	P192	P177
159	LUKE	P146	P194
172	LUKE	P211	P252
201	LUKE	P117	P133
192	LANG	P142	P152
203	LANG	P322	P404
211	LANG	P411	P362
233	LANG	P507	P333
251	LANG	P172	P125
262	LANG	P183	P179

SPARES

4 ENGINES REQUIRED TO SUPPORT DEPLOYMENT.

S/N	BASE	LOC	STATUS
P106	LUKE	SHOP	SERV
P159	LUKE	162R	SERV
P244	LUKE	SHOP	SERV
P272	LANG	SHOP	SERV

COMMAND:

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen A-3 shows only the tail numbers, serial numbers, and locations of the recommended engines and aircraft. Is there additional information you would require?

____

____

____

2. Rate the effectiveness of using an AMS interactive program to plan deployments.

very valuable _______ : _______ : _______ : _______ : _______ worthless

strongly approve _______ : _______ : _______ : _______ : _______ strongly disapprove

3. Is there additional information that should be requested from the user on screens A-1 and A-2? If so, write these items on screen A-1.

4. Comment on Display System A:

____

____

____

Figure 32 Survey Module QI

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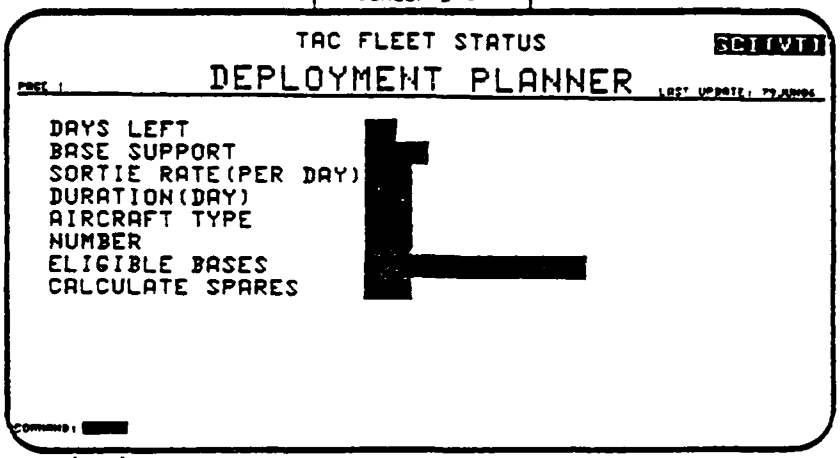
DISPLAY SYSTEM B

You request the automated management system (AMS) to provide the TACTICAL DEPLOYMENT PLANNER. Screen B-1 appears on your video terminal. The PLANNER is user-interactive. You must specify information concerning the deployment.

SCREEN B-1



You input the information that you have been provided by HQUSAF (screen B-2).

SCREEN B-2

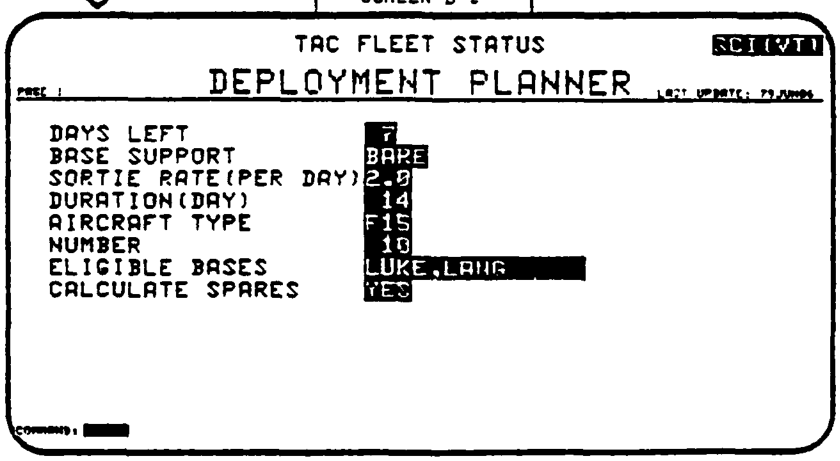


Figure 33 Survey Module QI

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DISPLAY SYSTEM B (CONTINUED)

The AMS PLANNER recommends the best aircraft to support the deployment (screen B-3). JOINT GPA is the average of the individual engine's health rating. Current trim adjustment (ΔTIT in clicks remaining) and engine operating time (EOT) are supplied for each recommended engine.

Highlighted engine serial numbers (S/N) indicate you must install that spare.

SCREEN B-3

TAC FLEET STATUS

PAGE 1

DEPLOYMENT PLANNER

AIRCRAFT

A/C	BASE	S/N L	S/N R	JOINT GPA	ΔTIT L	ΔTIT R	EOT L	EOT R
124	LUKE	P192	P177	98.2	12	12	231.2	401.3
159	LUKE	P146	P194	96.4	8	11	331.2	329.3
172	LUKE	P211	[illegible]	97.4	10	11	421.6	301.3
201	LUKE	P117	P133	95.3	11	9	499.1	521.3
192	LANG	P142	P152	97.2	11	9	419.6	621.3
203	LANG	P322	P404	96.3	12	10	333.6	211.3
211	LANG	P411	P362	98.1	10	8	299.1	301.9
233	LANG	P807	P333	96.4	9	9	198.3	421.3
251	LANG	P172	P126	95.3	9	10	601.3	334.2
262	LANG	[illegible]	P179	97.8	10	10	421.9	399.9

COMMAND:

The AMS PLANNER recommends four spares. GPA is the measure of engine's health and performance.

SCREEN B-4

TAC FLEET STATUS

DEPLOYMENT PLANNER

SPARES

4 REQUIRED TO SUPPORT DEPLOYMENT

S/N	BASE	LOC	STATUS	GPA	ΔTIT	EOT
P106	LUKE	SHOP	SERV	98.9	10	521.3
P159	LUKE	162R	SERV	87.8	12	422.6
P244	LUKE	SHOP	SERV	98.1	10	391.3
P272	LANG	SHOP	SERV	97.3	9	303.9

COMMAND:

Figure 34 Survey Module QI

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screens B-3 and B-4 provide additional information (engine health, trim status, and engine operating time). Does this information affect the effectiveness of the AMS Deployment Planner?

   greatly increase ______ : ______ : ______ : ______ : ______ greatly decrease

2. Evaluate the desirability of having the Deployment Planner calculate the spare engine requirements.

   very valuable ______ : ______ : ______ : ______ : ______ worthless

   strongly approve ______ : ______ : ______ : ______ : ______ strongly disapprove

3. Comment on Display System B:

   ____

   ____

   ____

Figure 35 Survey Module QI

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3.12 QJ-TCTO Assessment

Scenario:

As MAC engine manager, you have the responsibility for determining the impact on support operations and readiness of a proposed TCTO for the TF33P7 engine series. The TCTO would require the placement of the third-stage disc at 6000 cycles. The swapout procedure would be performed at the base unless the engine is slated for depot repair at or near the 6000 cycle limit. How many engines currently at the depot are eligible for modification? Based on MAC's programmed flying hours, how many engines will reach the 6000 cycle limit over the next six months (overall and by base)?

Scenario Objective:

This scenario requires the function of sorting all TF33P7 engines on location (depot) and cycle distribution. A forecasting function would be used to predict the number of engines reaching the 6000 limit in the six month planning horizon.

Display Formulation:

The TCTO assessment scenario is accompanied by display system A and B, (Figure 36, 37, 38, and 39). Display system A contains two screens of information; system B contains 3. Table 15 summarizes display density, format and special techniques.

Table 15
Module QJ Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density; Tabular	Low Density; Graphical
SCREEN 2	Meduim Density; Tabular	Low Density; Graphical
SCREEN 3		Low Density; Graphical

Analysis:

The depot report on the TF33P7 provides the distribution of engines by accumulated cycles. The participant compares tabular and graphical displays and evaluates their effectiveness. He also rates the criticality of providing additional information concerning an engine's location in the repair process. The participant identifies a requirement for additional information he would require before specifying which engines at the depot qualify for disc swapout.

Based on programmed flying hours the user accesses a forecast of the engines scheduled to reach the proposed 6000 cycle limit over the next months. The paticipant evaluates the tabular and graphical options for displaying this information command-wide and at the individual bases.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide cycle grouping of all TF33P7 engines at the depot. Screen A-1 appears on your video terminal. It shows the number of engines in each cycle interval. A-1 also groups the number of engines in each category that are in transit to the depot (TRANSIT), awaiting maintenance (AWM), in work (MAINT), or awaiting shipment to a base (SHIPPING).

SCREEN A-1

ENGINE FLEET STATUS

TF33 ENGINE

-TF33P7-

CYCLES	NUM	TRANSIT	AWM	MAINT	SHIPPING
0-4000	0	0	0	0	0
4000-4500	3	1	0	1	1
4500-5000	8	3	2	2	1
5000-5500	12	1	5	5	1
5500-6000	13	2	6	4	1
OVER 6000	2	0	1	0	1
TOTAL	38				

COMMAND:

REQUESTED: GROUP/CYCLE/P7,DEPOT

The system request is repeated for reference.

You now request the AMS to forecast the number of TF33P7 engines that will reach 6000 cycles over the next six months. Screen A-2 appears.

SCREEN B-2

ENGINE FLEET STATUS

TF33 ENGINE

-TF33P7-

FORECAST: ENGINES > 6000 CYCLES

BASE	JULY	AUG	SEPT	OCT	NOV	DEC
BOLLING	3	5	5	7	5	5
CHRLSTON	5	7	6	11	9	7
DOVER	7	10	9	12	12	9
MEMPHIS	2	4	3	5	5	5
VAN NUYS	3	4	5	4	4	5
TOTAL	20	30	28	39	35	31

COMMAND:

REQUESTED: FORECAST/P7/6000C

The system request is repeated for reference.

Figure 36 Survey Module QJ

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STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Screen A-1 shows cycles information for engines at the depot. Rate the value of including the engines' location in the repair process (in Transit, AWM, etc.).

   critical ________ : ________ : ________ : ________ : ________ useless

2. What further information would you require before determining which engines at the depot would be candidates for the third-stage disc swapout?

   ____

   ____

   ____

3. Comment on Display System A:

   ____

   ____

   ____

Figure 37 Survey Module QJ

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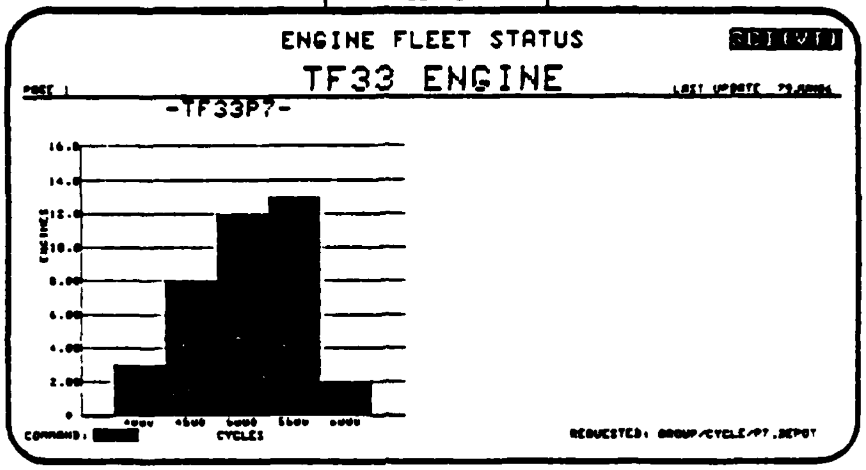
DISPLAY SYSTEM B

You request your AMS to provide the cycle grouping of all TF33P7 engines at the depot. Screen B-1 appears on your video terminal. It shows the number of engines in each cycle interval.

SCREEN B-1



The system request is repeated for reference.

You now request the AMS to forecast the number of TF33P7 engines that are scheduled to reach 6000 cycles over the next six months. The forecast for the entire fleet appears on the left side of the video terminal (screen B-2).

SCREEN B-2

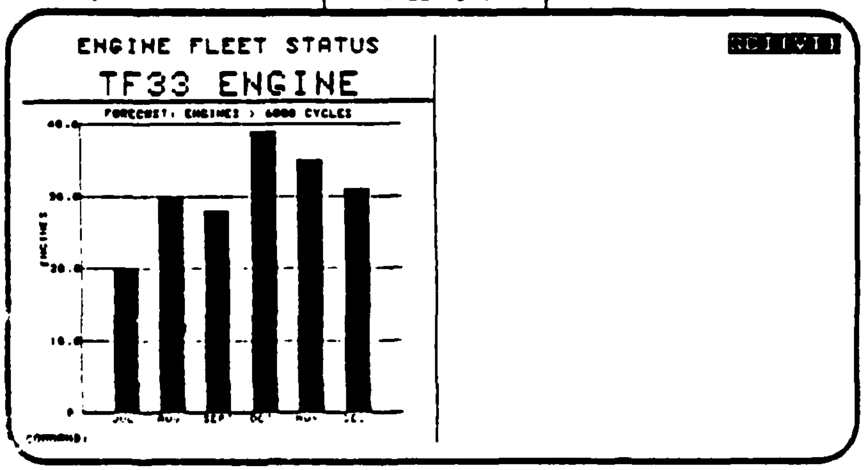


Figure 38 Survey Module QJ

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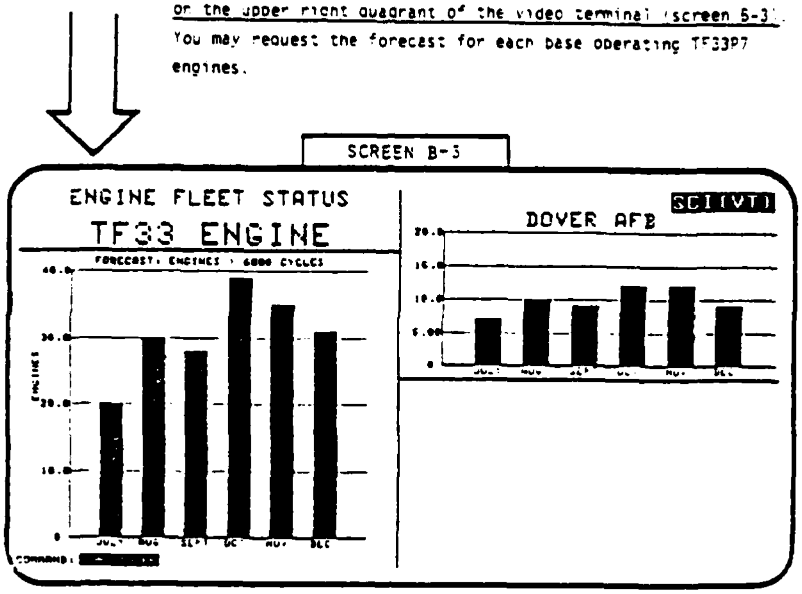
DISPLAY SYSTEM B (CONTINUED)

You now request to see the forecast for Dover AFB. It appears on the upper right quadrant of the video terminal (screen B-3). You may request the forecast for each base operating TF33P7 engines.



The last system request is retained for reference.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. Rate the effectiveness of graphing the cycle interval information for the engines at the depot.

   very effective _____ : _____ : _____ : _____ : _____ ineffective

2. How would the screen's effectiveness change if the right side of screen B-1 included information on the engines' location in the repair process (in TRANSIT, AWM, etc.)?

   greatly increase _____ : _____ : _____ : _____ : _____ greatly decrease

3. How valuable is the bar graph representation used to display the numbers of the engine in screens B-2 and B-3?

   extremely beneficial _____ : _____ : _____ : _____ : _____ worthless

   _____ I don't understand it

4. Comment on Display System B:

   ____

   ____

   ____

Figure 39 Survey Module QJ PROCEED TO NEXT PAGE

5.13 QK-Spare Engine Status

Scenario:

As SAC engine manager, it is your duty to monitor spare engine status. You what to identify bases with:

- long queues of engines awaiting maintenance
- high rates of engines that are not mission capable due to supply (ENMCS)
- engines assigned to maintenance for over 45 days

You can access an automated management system (AMS) to provide you with this information.

Scenario Objective:

This scenario illustrates grouping of uninstalled engine by status, command wide. On a daily basis, the MAJCOM engine manager is primarily interested in identifying only bases that have attributes that exceed some established limit. The questions are directed towards a procedure for establishing the limits. It is also important to identify any requirement for tracking and trending the data historically.

Display Formualtion:

The spare engine status scenario is accompanied by display system A and B, (figure 40 and 41). Each display system contains one screen of information. Table 16 summarizes display density, format, and special techniques.

Table 16
Module QK Display Formulation

	SYSTEM A	SYSTEM B
SCREEN 1	High Density; Tabular Inverse Video	Medium Density; Tabular; Inverse Video; Management By Exception

Analysis:

The spare engine status report is a MAJCOM level display. Its purpose is to provide the MAJCOM engine manager with a snapshot of his command's repair and resupply status. He would use this report to identify bases with spare engine problems such as those discussed in the scenario. The survey evaluates the factors the engine manager needs to monitor. The survey paticipant rates the alternative for managing the engine status on exception and discusses the formulation of appropriate "flags". The participant indicates the value of automatically trending certain of the factors (e.g. ENMCS) for a user-specified base and engine TMS.

DISPLAY SYSTEM A

You request your automated management system (AMS) to provide the SAC spare engine report. Screen A-1 appears. It lists SAC bases by engine type, model, and series (TMS). The RATE is the % ratio of uninstalled to installed engines. The number of serviceable engines are identified by position (1, 2, 3, or 4). A-1 displays the number of engines in maintenance (MAINT), awaiting maintenance (AWM), and not mission capable due to supply (ENMCS). The OVER 45 category identifies a "hangar queen" in the shop for over 45 days. You can continue to display groups of bases for other SAC engine TMS by a simple terminal input.

SCREEN A-1

SAC FLEET MONITOR SCI(VT)

SPARE ENGINE STATUS LAST UPDATE:

BASE	ENG TYPE	RATE	SERV 1234	MAINT	AWM	ENMCS	OVER 45
KISAWYR	TF33-3	13%	2202	1	2	2	0
CASTLE	TF33-3	12%	0111	2	0	2	0
ELSWRTH	TF33-3	19%	1001	5	7	10	2
GRNDFKS	TF33-3	14%	1223	2	0	2	0
MINOT	TF33-3	16%	2222	3	0	1	0
TOTAL			7869	13	9	17	2
KADENA	TF33-5	11%	1000	0	0	1	0
OFFUIT	TF33-5	14%	2000	1	0	5	0
SHEMYA	TF33-5	14%	1010	0	0	0	0
TOTAL			4010	1	0	6	0

MORE?

Highlighted areas flag spares problems.

Elsworth AFB has 10 engines down due to supply and 2 hangar queens.

OFFUIT has 5 engines down for supply.

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. In screen A-1 the bases with spare engine problems are highlighted. Rate the effectiveness of this technique.

   very effective ________:________:________:________:________ ineffective

2. Is there any additional information you would want displayed for those engines classified as MAINT, AWM, or ENMCS?

3. Would you prefer a measure other than the ratio % of uninstalled to installed engines (spares rate) used in screen A-1?

4. Comment on Display System A:

Figure 40 Survey Module QK

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DISPLAY SYSTEM B

You request your AMS to provide the SAC spare engine report. Screen B-1 appears. It lists only those bases with an engine spares problem. As of 06 June 1979, four bases have been flagged for engine management attention. The specific problems are highlighted for each base.

SCREEN B-1

SAC FLEET MONITOR

SPARE ENGINE STATUS

THE FOLLOWING BASES HAVE BEEN FLAGGED

BASE	ENG TYPE	RATE	SERV 1234	MAINT	AWM	ENMCS	OVER 45
ELSWRTH	TF33-3	19%	1001	5	7	10	2
OFFUIT	TF33-5	14%	2000	1	0	5	0
DYESS	J57-29	16%	0200	3	5	5	0
ROBINS	J57-43	15%	1102	4	2	3	3

STOP PLEASE ANSWER THESE QUESTIONS BEFORE PROCEEDING.

1. In Screen B-1 only the bases with spare engine problems are displayed. *Rate the effectiveness of this technique.*

   very effective ______ : ______ : ______ : ______ : ______ ineffective

2. Discuss how to develop the appropriate factors to use as flags in System B.

   ____

   ____

   ____

3. Suppose the AMS supplied System B as a daily report and System A as a weekly report. Rate the effectiveness of that option.

   very effective ______ : ______ : ______ : ______ : ______ ineffective

4. Rate the benefits of the capability to automatically trend over time the numbers of engines that are ENMCS for a particular base and engine TMS.

   very valuable ______ : ______ : ______ : ______ : ______ worthless

5. Comment on Display System B:

   ____

   ____

   ____

Figure 41 Survey Module QK

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APPENDIX C

ENGINE MAINTENANCE SUPPORT SYSTEM SURVEY RESPONSES

I. INTRODUCTION

This section accumulates the results of the support system survey. In Section II , responses for each maintenance scenario question as presented. Analysis of the numerical significance of the returns is provided. In addition to the response tallies, comments provided by respondents to each question are summarized. In Section III, tallies of cumulative issues and functional capability evaluations across survey scenarios are provided. Additional analysis describes the significance of the results.

Each response item is tabulated with the response frequency in each category plotted in bargraph form. Statistics of the response distribution are calculated and may provide some insight into the interpretation of the response significance. The factors calculated are defined below.

Define: N = number of survey responses

x_i = value of classification (e.g., 1,2,3,4, or 5)

Then, mean response: $m = \frac{1}{N}\sum_{i=1}^{N} x_i$

Std. Deviation: $s = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - m)^2$

90% Confidence: $L_{90} = \pm t_{.95,N-1}\,s$

80% Confidence: $L_{80} = \pm t_{.90,N-1}\,s$

where $t_{\alpha,n}$ is the Student's t distribution value with power α and n degrees of freedom. The significance of the confidence interval is that the probability of the normal population mean lying within the confidence band around the sample mean is the power of the test, or

$$Pr(m-L \leq \bar{x} \leq m+L) = \frac{\alpha}{2} \quad .$$

Caution should be used in evaluating classified statistical hypothesis test results. Statistical measures do provide useful quantification of an otherwise qualitative process.

II. SURVEY RESULTS ACCUMULATED BY SCENARIO

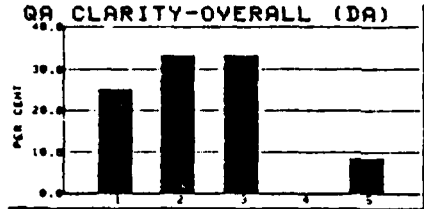
The following section presents freqeuncy tabulations of survey responses by question. Survey questions and objectives are presented in other sections of the report.

2.1 Question A - Bare Base Deployment

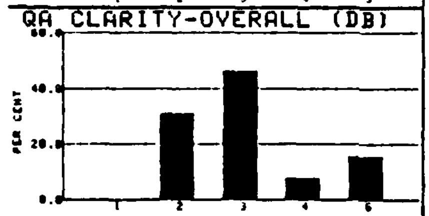
The scenario address base fleet readiness assessment for deployment to an unsupported location. System A contains less dense information using more graphical display options.

Figure 1 shows the system ratings. System A is rated more clear than System B. Both systems are perceived to have sufficient content and no conclusion can be reached concerning their effectiveness compared to existing methods.

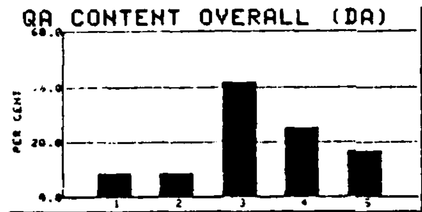
Figure 2 presents the results to miscellaneous questions. A wide spread in GPA ranking confidence is indicative of uncertainty concerning either its meaning or effectiveness. Both status summaries were perceived to have sufficient data for quick assessment of base readiness.



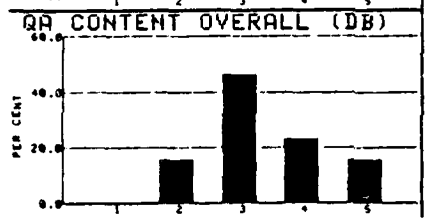
NO.OF RETURNS= 12.
MEAN RESPONSE= 2.33
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.4
1. - Very Clear
5. - Obscure



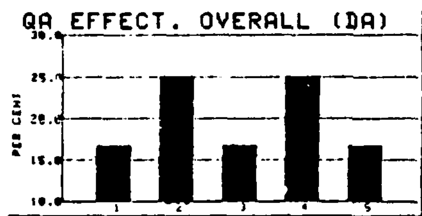
NO.OF RETURNS= 13.
MEAN RESPONSE= 3.08
STD.DEVIATION= 1.0
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3
1. - Very Clear
5. - Obscure



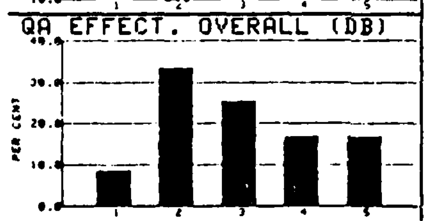
NUMB OF RESPONSES= 12.
MEAN RESPONSE= 3.33
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.4
1. - Too Much
3. - Enough
5. - Too Little



NUMB OF RESPONSES= 13.
MEAN RESPONSE= 3.38
STD.DEVIATION= .92
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2
1. - Too Much
3. - Enough
5. - Too Little

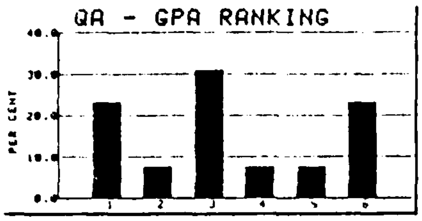


NUMB OF RESPONSES= 12.
MEAN RESPONSE= 3.00
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.4
80 PCT CONFID=+/- 1.8
1. - More Effective
3. - Same
5. - Less Effective

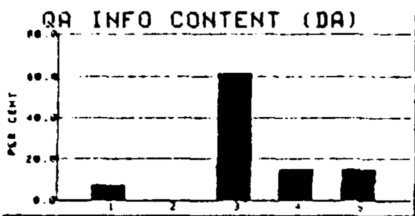


NUMB OF RESPONSES= 12.
MEAN RESPONSE= 3.00
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6
1. - More Effective
3. - Same
5. - Less Effective

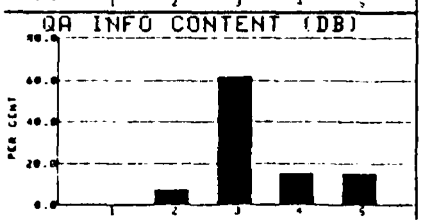
Figure 1 Display System Rating Response



NUMB OF RESPONSES= 13.
MEAN RESPONSE= 3.38
STD.DEVIATION= 1.8
90 PCT CONFID=+/- 3.3
80 PCT CONFID=+/- 2.4
1. - Very Valuable
5. - Worthless
6. - Unable to Score



NO.OF RETURNS= 13.
MEAN RESPONSE= 3.31
STD.DEVIATION= .99
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3
1. - Too Much
3. - Enough
5. - Too Little



NO.OF RETURNS= 13.
MEAN RESPONSE= 3.38
STD.DEVIATION= .84
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1
1. - Too Much
3. - Enough
5. - Too Little

Figure 2 Response to Miscellaneous Questions

Figure 3 presents system preference responses. System A was marginally preferred over System B with a large percent without preference.

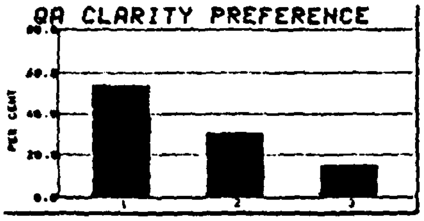
Table 1 tabulates comments. System A status summary is preferred with the high density ranking displays. Spares rate rate was mentioned as a candidate for elimination. Task force results reinforced both comments.

2.2 Question B - Pilot Squawk

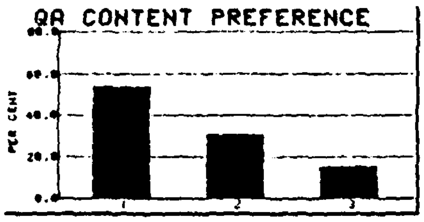
This scenario poses a diagnostic/troubleshooting requirement on an uninstalled engine. System A uses tabular data formats while System B employs graphics. Engine profile A has low density summary items. Trending capability is provided by System B alone.

Both systems (Figure 4) were rated clear. System A was judged as being deficient in content and there was not a consensus concerning its effectiveness against existing methods. The addition of trending capability (System B) increased the content rating and it significantly improved the perception of effectiveness of function. This conclusion is reinforced in the system preferences (Figure 5) which shows that the addition of trending is perceived to be valuable. The responses to miscellaneous questions (Figure 6) corroborate the value of the GPA as understood and used against the scenario requirements.

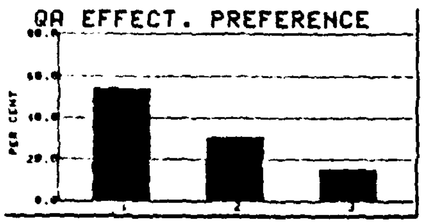
Other question responses and a large number of comments (Table 2) indicated that the bargraph representation was confusing and personnel preferred to use tabular data. The use of video highlights was endorsed. These results were reflected in task force commentary.



NUMB OF RESPONSES= 13.
MEAN RESPONSE= 1.62
STD.DEVIATION= .74
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .96



NUMB OF RESPONSES= 13.
MEAN RESPONSE= 1.62
STD.DEVIATION= .74
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .96



NUMB OF RESPONSES= 13.
MEAN RESPONSE= 1.62
STD.DEVIATION= .74
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .96

1. - System A
2. - System B
3. - No Preference

Figure 3 Display System Preferences

Table 1

Bare Base Deployment - Survey Comments

COMMENT	FREQUENCY
• ENGINES ARE ONLY A SMALL PART OF DEPLOYMENT DECISION - EVALUATE ENGINES ONLY IN AIRCRAFT QUALIFIED TO DEPLOY	1
• PAST PERFORMANCE VERY USEFUL IN DEPLOYMENT DECISIONS	1
• ELIMINATE SPARES RATE ON BASE SUMMARY	4
• SHOW % COMPLETE FOR MAINT, AWM, ENMCS CATEGORIES	1
• ADD MORE PIPELINE SEGMENTS TO SUMMARY	1
• DISPLAY AIRCRAFT HOLES	1
• EXCEPTION REPORTING EXTREMELY IMPORTANT	1
• DISPLAY SCHEDULED MAINTENANCE AS A STATUS MESSAGE	1
• MAKE COLUMN CATEGORIES APPLY TO ALL TYPES ENGINES (TF34 DOESN'T COUNT CLICKS)	1
• LIFE LIMITS IN ENGINE OPERATING TIME REMAINING	1
• SHOW FTIT - LAST TRIM VS PRESENT	1
• HST MUST RELATE TO CURRENT HPT	1
• SHOW SOAP TREND	1
• A-SUMMARY WITH B-2/B-3	4
• B-SUMMARY with A-2/A-3	1

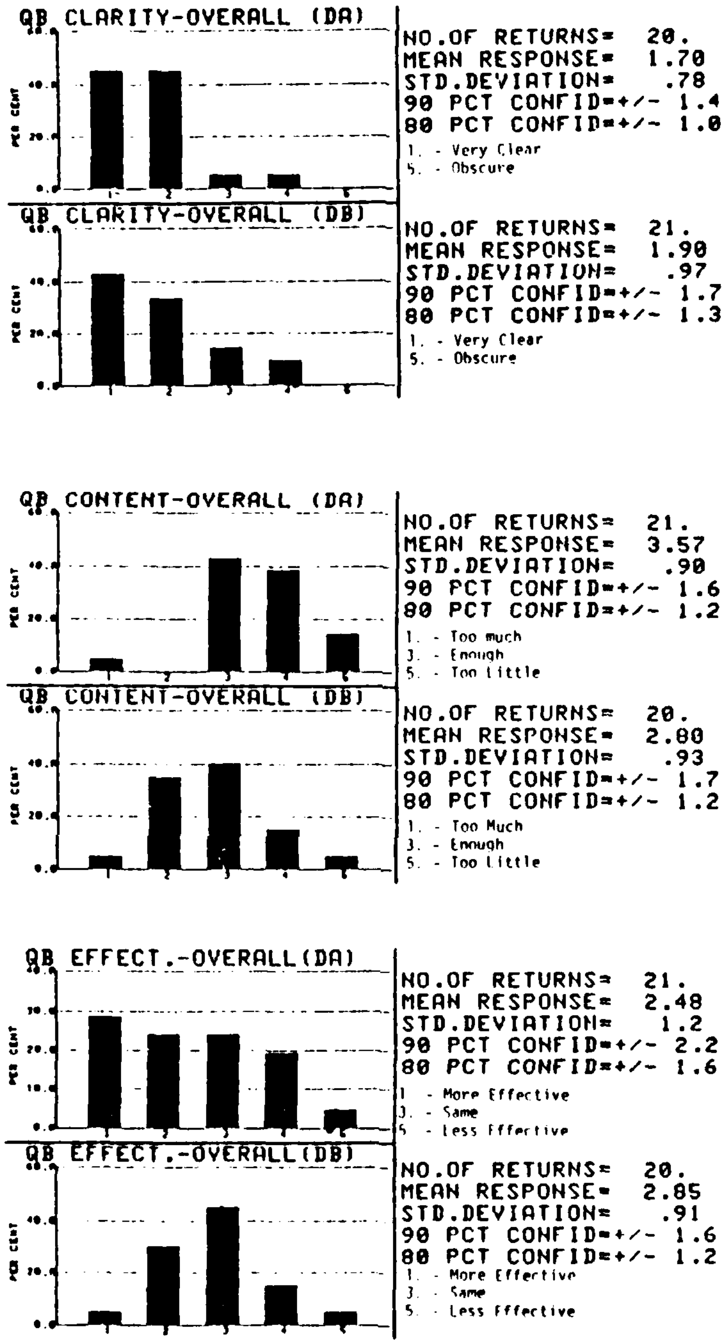


Figure 4 Display System Rating Response

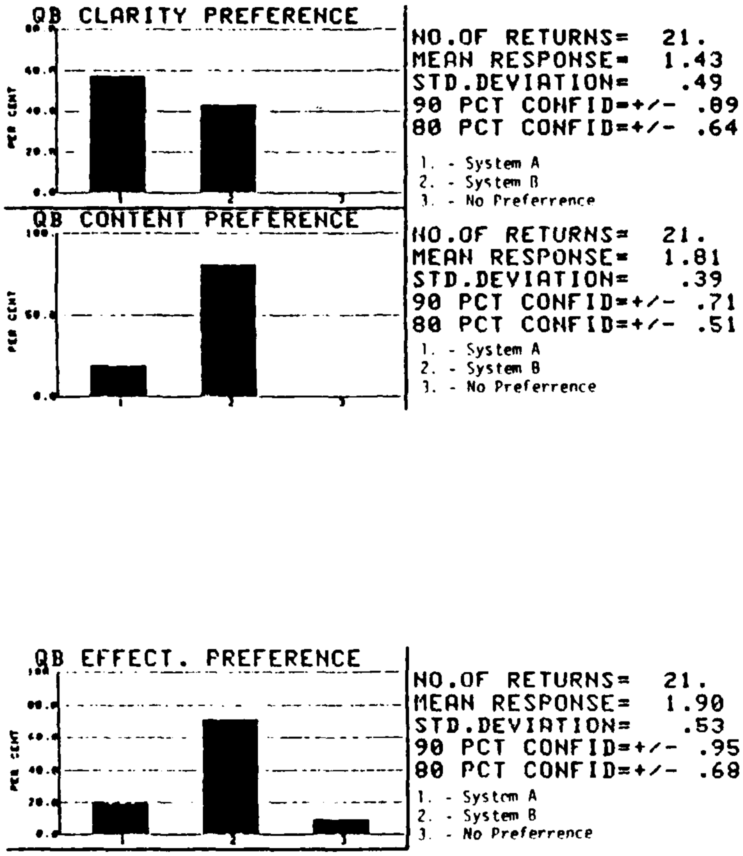
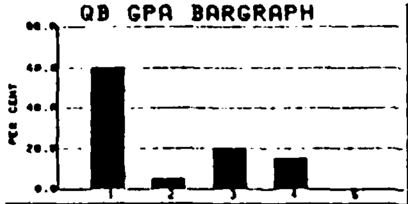


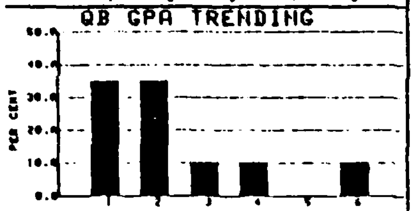
Figure 5 Display System Preferences

QB GPA BARGRAPH



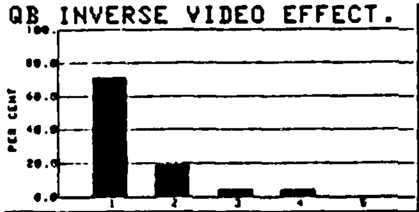
NO.OF RETURNS= 20.
MEAN RESPONSE= 1.90
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.1
80 PCT CONFID=+/- 1.5
1. - Very Effective
5. - Ineffective

QB GPA TRENDING



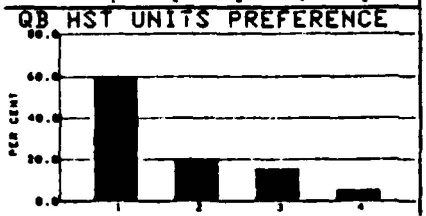
NO.OF RETURNS= 20.
MEAN RESPONSE= 2.35
STD.DEVIATION= 1.5
90 PCT CONFID=+/- 2.7
80 PCT CONFID=+/- 2.0
1. - Very Helpful
5. - Useless
6. - Unable to Score

QB INVERSE VIDEO EFFECT.



NUMB OF RESPONSES= 21.
MEAN RESPONSE= 1.43
STD.DEVIATION= .79
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0
1. - More Effective
3. - Same
5. - Less Effective

QB HST UNITS PREFERENCE



NUMB OF RESPONSES= 20.
MEAN RESPONSE= 1.65
STD.DEVIATION= .91
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.2
1. - System A
2. - System B
3. - No Preference

Figure 6 Response to Miscellaneous Questions

Table 2

QB - Pilot Squawk - Survey Comments

COMMENT	FREQUENCY
• FLAGGING SYSTEM IS EXCELLENT	2
• WOULD LIKE HARD LIMIT THRESHOLD FOR GPA	1
• USE TABULAR GPA SNAPSHOT WITH GPA TREND (ELIMINATE BAR-GRAPH)	4
• WHAT IS AN ACCEPTABLE TREND?	1
• TREND SHOULD HELP WITH LOCAL FORECAST OF REMOVALS	2
• I LIKE TREND INFORMATION ON GPA	3
• WHAT WERE ENGINE CONDITIONS AT TIME OF REPORTED DISCREPANCY? (N1, N2, ETC.)	1
• WHAT IS THE RATE OF HOT SECTION ACCRUAL?	1
• ONLY ONE TREND PER GRAPH	1
• THIS INFORMATION SHOULD ALSO BE MADE AVAILABLE TO AGS PEOPLE	1
• WHAT MAINTENANCE ACTION IS REQUIRED TO GET ENGINE BACK TO 100% GPA	2
• GRAPHS MAY CONFUSE PERSONNEL AT WORKING LEVELS	2
• DISPLAYS MUST BE KEPT CURRENT TO BE OF ANY USE	1
• LAST BORESCOPE STATUS?	1
• USE B-PROFILE WITH TABULAR GPA SNAPSHOT	4
• USE A-PROFILE WITH GPA TREND	2

2.3 Question C - Engine Alarm

The scenario illustrates troubleshooting diagnostic procedures for an off idle stall. Management by exception, alarms, indexing and data access are illustrated. System A contains a low density tabular format. System B contains full summary data items on profile.

Figure 7 presents the system rating responses which were not significantly different for both systems. The respondants indicated the information was clear and approximately enough was provided. There was a range of opinions concerning the effectiveness, which provides no conclusions in this regard. Figure 8 shows that the denser profile display (B) was significantly favored with regard to trend effectiveness. This is underscored by the large number of comments (Table 3) suggesting interchanging Base Summary Status products. Miscellaneous question responses are shown in Figure 9.

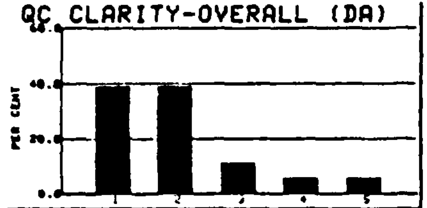
2.4 Question D - TCTO Management

This scenario addresses TCTO Management at the base level. System A contains high density tabular formats and system B uses lower density, graphical output. System C uses low density, tabular output only.

Figure 10 shows the display ratings. System C is judged clear in interpretation. All systems contain enough information. Systems A and C are rated effective in addressing the scenario information requirements.

Figure 11 presents the results to miscellaneous questions. Inverse video highlighting was deemed an effective format. Bargraphs are marginally clear. Life limit horizon preference is 100 hours which is consistent with task force comments. SORTING capability for this scenario is extremely beneficial in addressing the scenario requirements.

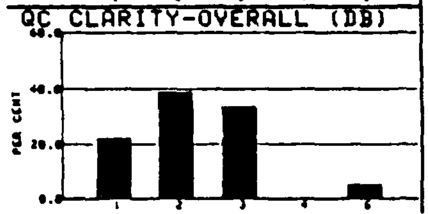
QC CLARITY-OVERALL (DA)



NO.OF RETURNS= 18.
MEAN RESPONSE= 2.00
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.4

1. - Very Clear
5. - Obscure

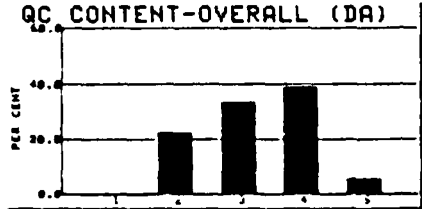
QC CLARITY-OVERALL (DB)



NO.OF RETURNS= 18.
MEAN RESPONSE= 2.28
STD.DEVIATION= .99
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3

1. - Very Clear
5. - Obscure

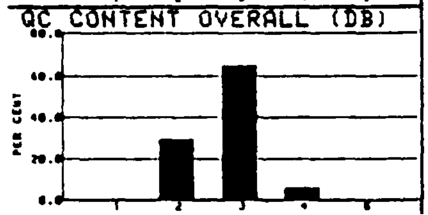
QC CONTENT-OVERALL (DA)



NO.OF RETURNS= 18.
MEAN RESPONSE= 3.28
STD.DEVIATION= .87
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.1

1. - Too Much
3. - Enough
5. - Too Little

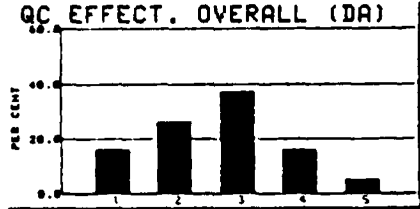
QC CONTENT OVERALL (DB)



NO.OF RETURNS= 17.
MEAN RESPONSE= 2.76
STD.DEVIATION= .55
90 PCT CONFID=+/- .98
80 PCT CONFID=+/- .71

1. - Too Much
3. - Enough
5. - Too Little

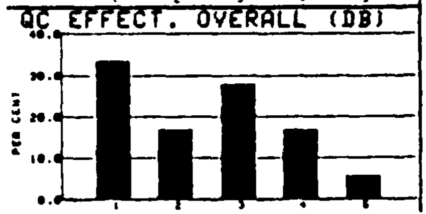
QC EFFECT. OVERALL (DA)



NO.OF RETURNS= 19.
MEAN RESPONSE= 2.68
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 1.9
80 PCT CONFID=+/- 1.4

1. - More Effective
3. - Same
5. - Less Effective

QC EFFECT. OVERALL (DB)



NO.OF RETURNS= 18.
MEAN RESPONSE= 2.44
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.6

1. - More Effective
3. - Same
5. - Less Effective

Figure 7 Display System Rating Response

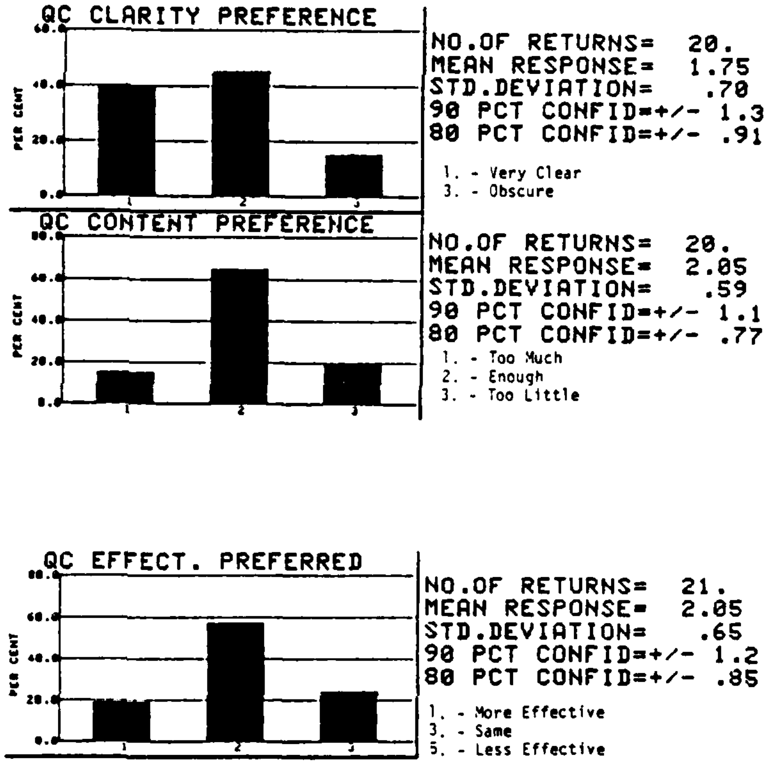
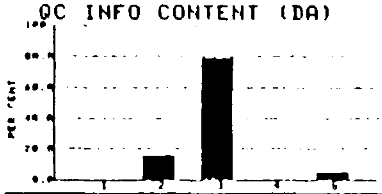


Figure 8 Display System Preferences

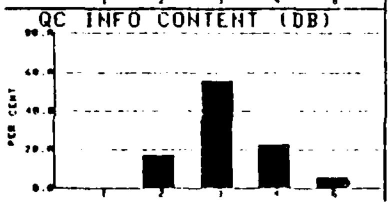
Table 3

QC Engine Alarm - Survey Comments

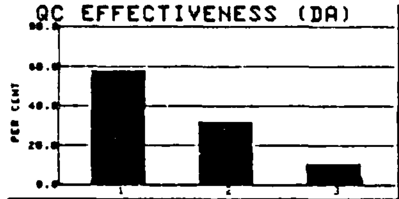
COMMENT	FREQUENCY
• NEED MORE DIAGNOSTIC INFORMATION PROFILE	4
• SINGLE POINT DIAGNOSTICS ARE ONLY MARGINALLY ADEQUATE - NEED TO ACCESS TRENDS	1
• WHAT ARE POSSIBLE CAUSES OF ALARM BESIDES RCVV (WHAT ARE THEIR PROBABILITIES?)	1
• INCLUDE BORESCOPE RESULTS ON PROFILE	1
• SHOW NEXT MAINTENANCE ACTION ON PROFILE - DISPLAY LAST ACTION AS WELL	2
• HST MUST RELATE TO CURRENT HPT	1
• ALWAYS SHOW WHETHER SENSORS ARE OPERATING	1
• REMOVE SPARES RATE	4
• SHOW % COMPLETE FOR MAINT, ENMCS, AWM CATEGORIES	1
• PROVIDE A BASE SUMMARY WITH B PROFILE	6



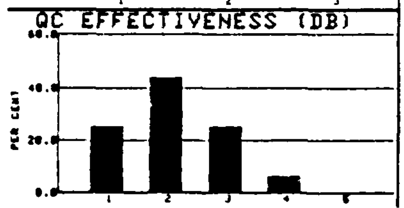
NO.OF RETURNS= 19.
MEAN RESPONSE= 2.95
STD.DEVIATION= .60
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .79
1 - Too Much
3 - Enough
5 - Too Little



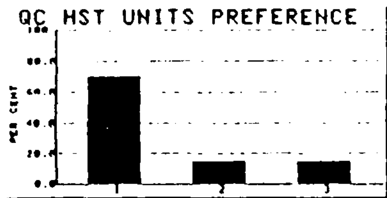
NO.OF RETURNS= 18.
MEAN RESPONSE= 3.17
STD.DEVIATION= .76
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- .99
1. - Too Much
3. - Enough
5. - Too Little



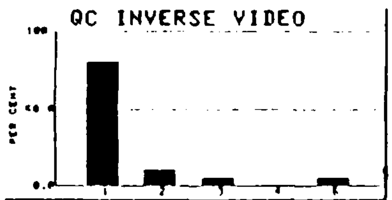
NO.OF RETURNS= 19.
MEAN RESPONSE= 1.53
STD.DEVIATION= .68
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .88
1. - More Effective
2. - Same
3. - Less Effective



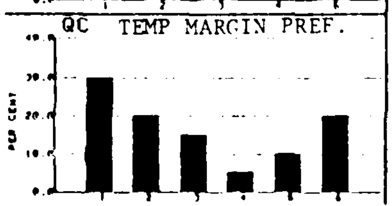
NO.OF RETURNS= 16.
MEAN RESPONSE= 2.13
STD.DEVIATION= .86
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1
1. - More Effective
3. - Same
5. - Less Effective



NO.OF RETURNS= 20.
MEAN RESPONSE= 1.45
STD.DEVIATION= .74
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .96
1. - Hours
2. - Percent
3. - Both



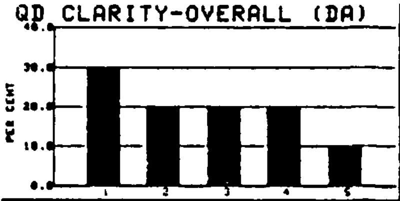
NO.OF RETURNS= 20.
MEAN RESPONSE= 1.40
STD.DEVIATION= .97
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.3
1 - Very Effective
5 - Ineffective



NO.OF RETURNS= 20.
MEAN RESPONSE= 3.05
STD.DEVIATION= 1.9
90 PCT CONFID=+/- 3.4
80 PCT CONFID=+/- 2.5
1 - Extremely Essential
5 - Worthless
6 - Unable to Score

Figure 9 Response to Miscellaneous Questions

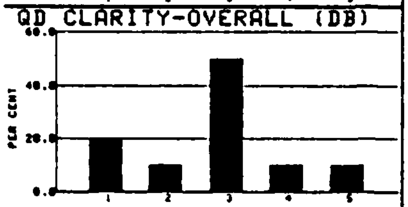
QD CLARITY-OVERALL (DA)



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.60
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.4
80 PCT CONFID=+/- 1.8

1. - Very Clear
5. - Obscure

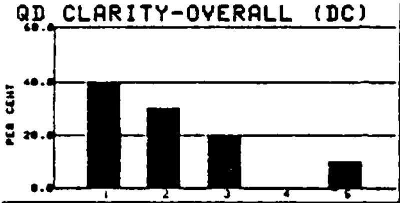
QD CLARITY-OVERALL (DB)



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.80
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.1
80 PCT CONFID=+/- 1.5

1. - Very Clear
5. - Obscure

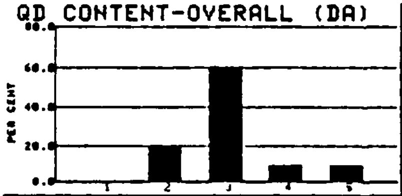
QD CLARITY-OVERALL (DC)



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.10
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6

1. - Very Clear
5. - Obscure

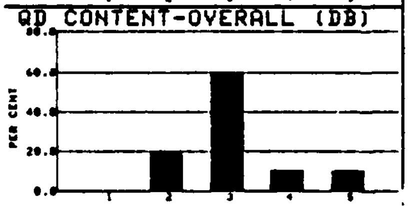
QD CONTENT-OVERALL (DA)



NO.OF RETURNS= 10.
MEAN RESPONSE= 3.10
STD.DEVIATION= .83
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1

1. - Too Much
3. - Enough
5. - Too Little

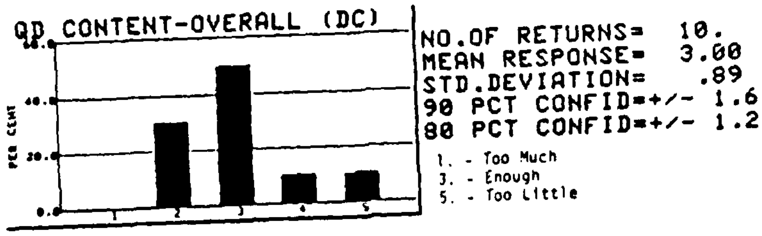
QD CONTENT-OVERALL (DB)

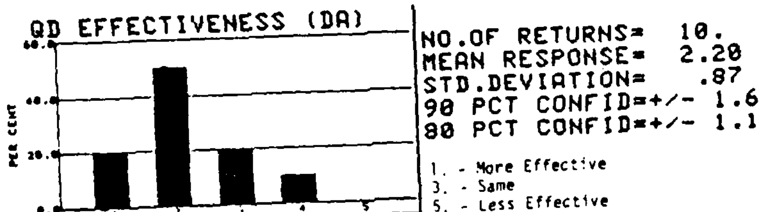


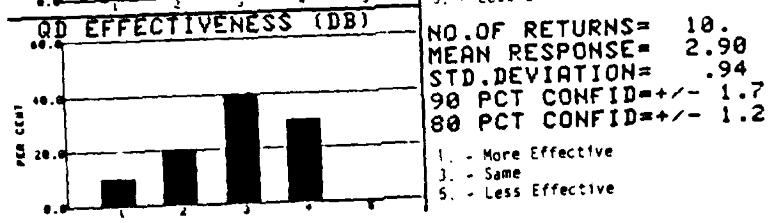
NO.OF RETURNS= 10.
MEAN RESPONSE= 3.10
STD.DEVIATION= .83
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1

1. - Too Much
3. - Enough
5. - Too Little

Figure 10 Display System Rating Response







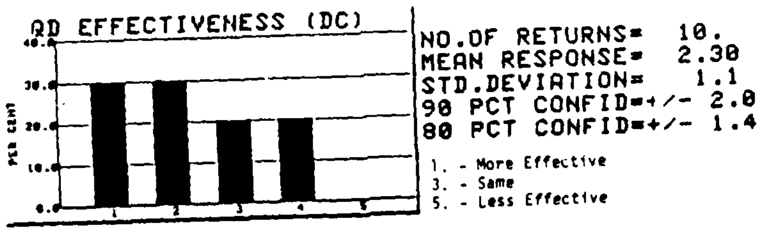
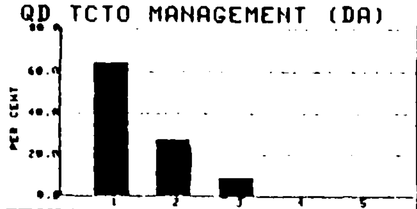


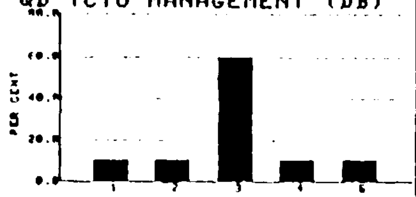
Figure 10 Display System Rating Response (Continued)

QD TCTO MANAGEMENT (DA)



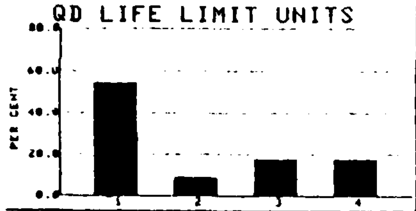
NO.OF RETURNS= 11.
MEAN RESPONSE= 1.45
STD.DEVIATION= .66
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .85
1. - Very Effective
5. - Ineffective
HIGHLIGHTS

QD TCTO MANAGEMENT (DB)



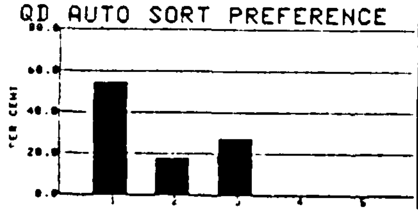
NO.OF RETURNS= 10.
MEAN RESPONSE= 3.00
STD.DEVIATION= 1.0
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3
1. - Very Clear
5. - Obscure
BARGRAPH

QD LIFE LIMIT UNITS



NO.OF RETURNS= 11.
MEAN RESPONSE= 2.00
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6
1. - 100 Hours
2. - 200 Hours
3. - Component Closest to Limit
4 - No Comment

QD AUTO SORT PREFERENCE



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.73
STD.DEVIATION= .86
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.1
1. Extremely beneficial
5. Worthless

Figure 11 Response to Miscellaneous Questions

Table 4 lists the survey comments. Bargraph interpretation appears to be troublesome. The use of generic column headings was notably favored.

Figure 12 shows the preferences. Systems A and C are nearly equal in user preference.

2.5 Squadron GPA Degradation

This scenario addresses the utilization of performance analysis to evaluate multiple installed engines. The display systems illustrate the GROUP capability with system A showing tabular format and System B utilizing graphical capabilities.

Figure 13 presents system ratings. System A is rated clear with sufficient information and more effective than current procedures. System B is rated unclear. There is no significant conclusion as to its effectiveness. These results are reaffirmed in the system preferences (Figure 14) where System A is overwhelmingly chosen.

Figure 15 presents the results of miscellaneous questions. Over 70% of the responses evaluated the squadron trends correctly. There was a significant spread in rating the graphical format of display B indicating a general uncertainty about it utility. The results of questions concerning System B should be discounted because of the lack of clarity in format. The ease and speed of usage of the GROUP function were rated in the maximal range indicating the utility of this function in addressing the scenario. Comments are listed in Table 5.

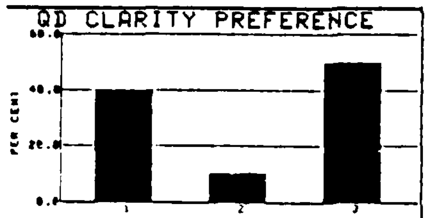
2.6 Question F - Base Maintenance Forecast

The scenario addresses base level forecasting of engine removals for usage and performance. Tabular usage removal

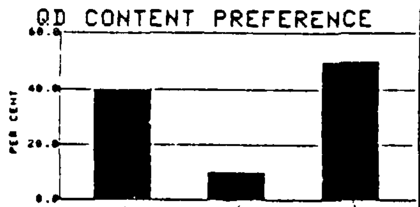
Table 4

QD - TCTO Management - User Comments

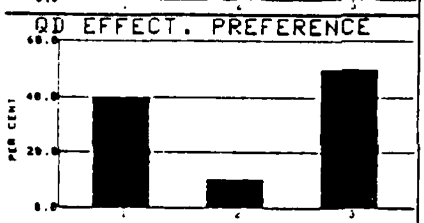
COMMENT	FREQUENCY
• LIFE LIMIT BAR GRAPH CONFUSING	4
• USE GENERIC INFORMATION CATEGORIES	3
• WHEN MUST TCTO BE ACCOMPLISHED?	1
• WANT LIFE LIMITS IN ENGINE OPERATING TIME REMAINING	2



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.10
STD.DEVIATION= .94
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2



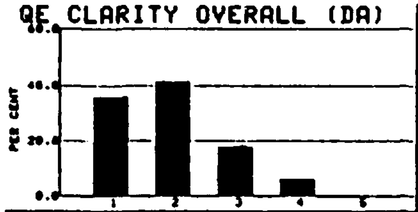
NO.OF RETURNS= 10.
MEAN RESPONSE= 2.10
STD.DEVIATION= .94
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.10
STD.DEVIATION= .94
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2

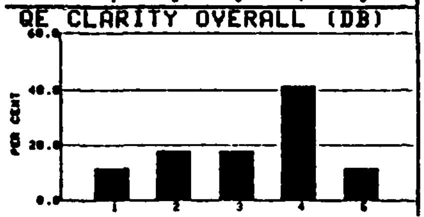
1. System A
2. System B
3. System C

Figure 12 Display System Preference



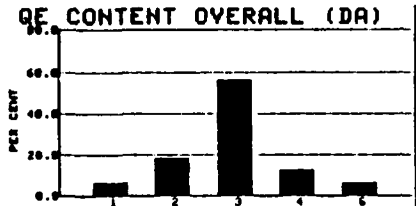
NO.OF RETURNS= 17.
MEAN RESPONSE= 1.94
STD.DEVIATION= .87
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.1

1. - Very Clear
5. - Obscure



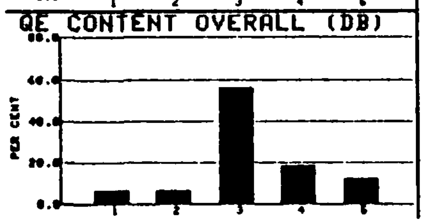
NO.OF RETURNS= 17.
MEAN RESPONSE= 3.24
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6

1. - Very Clear
5. - Obscure



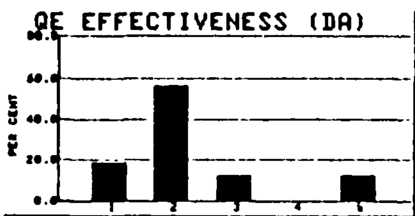
NO.OF RETURNS= 16.
MEAN RESPONSE= 2.94
STD.DEVIATION= .90
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.2

1. - Too Much
3. - Enough
5. - Too Little



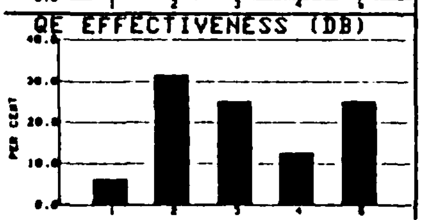
NO.OF RETURNS= 16.
MEAN RESPONSE= 3.25
STD.DEVIATION= .97
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.3

1. - Too Much
3. - Enough
5. - Too Little



NO.OF RETURNS= 16.
MEAN RESPONSE= 2.31
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.1
80 PCT CONFID=+/- 1.5

1. - More Effective
3. - Same
5. - Less Effective



NO.OF RETURNS= 16.
MEAN RESPONSE= 3.19
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.7

1. - More Effective
3. - Same
5. - Less Effective

Figure 13 Display System Rating Response

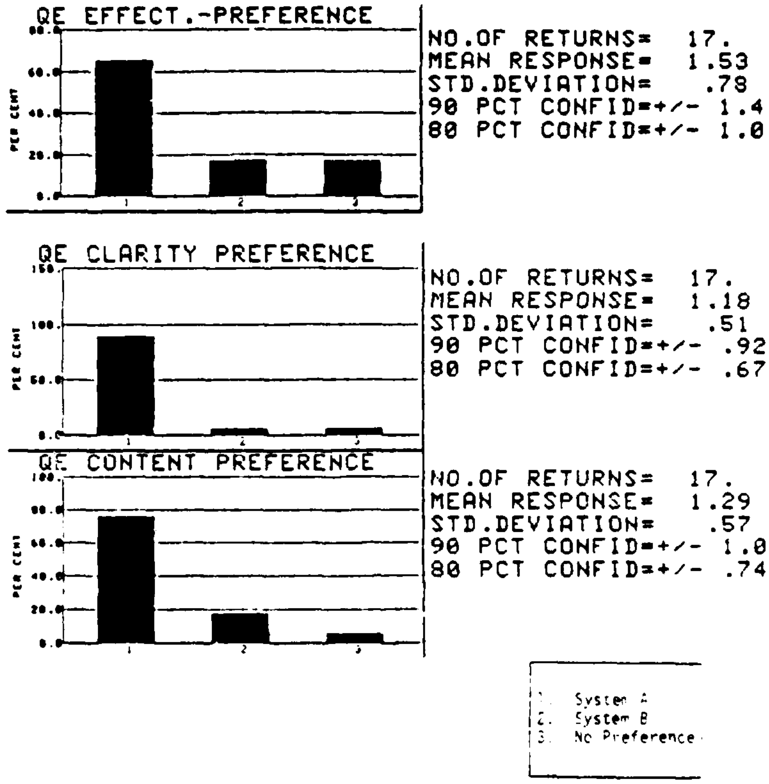
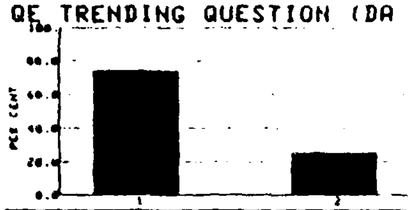
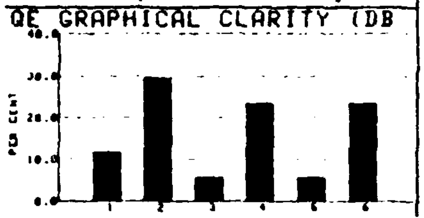


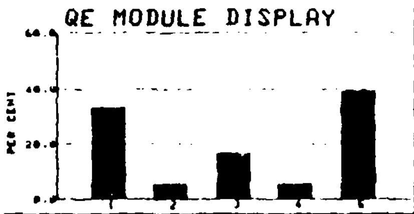
Figure 4 Display Preferences



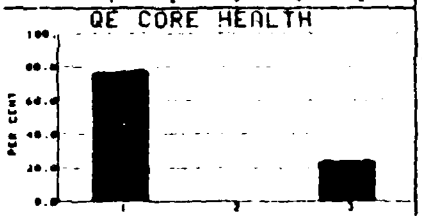
NO.OF RETURNS= 16.
MEAN RESPONSE= 1.25
STD.DEVIATION= .43
90 PCT CONFID=+/- .78
80 PCT CONFID=+/- .66
1 - Correct
2 - Incorrect



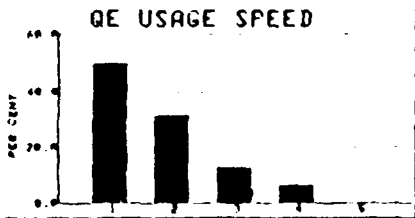
NO.OF RETURNS= 17.
MEAN RESPONSE= 3.53
STD.DEVIATION= 1.8
90 PCT CONFID=+/- 3.2
80 PCT CONFID=+/- 2.3
1 - Very Clear
5 - Obscure
6 - Unable to Score



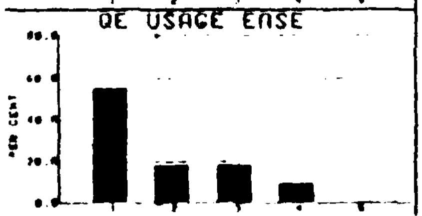
NO.OF RETURNS= 18.
MEAN RESPONSE= 3.11
STD.DEVIATION= 1.7
90 PCT CONFID=+/- 3.1
80 PCT CONFID=+/- 2.2
1 - No Additional Modules 5 - Turbines
2 - All Modules
3 - Unable to Score
4 - As Required



NO.OF RETURNS= 17.
MEAN RESPONSE= 1.47
STD.DEVIATION= .85
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1
1 Yes
2 No
3 No Answer



NO.OF RETURNS= 16.
MEAN RESPONSE= 1.75
STD.DEVIATION= .90
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.2
1 Very Quickly
5 Very Slowly



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.82
STD.DEVIATION= 1.0
90 PCT CONFID=+/- 1.9
80 PCT CONFID=+/- 1.3
1 - Very Easily
5 With Great Difficulty

Figure 15 Response to Miscellaneous Questions

Table 5

QE Squadron GPA Degredation - Survey Comments

COMMENT	FREQUENCY
• TABULAR DISPLAY CONFUSING - TOOK TOO LONG TO ANALYZE	1
• DON'T UNDERSTAND BAR GRAPH	2
• PREFER HAVING THE NUMBERS LIKE ON TABULAR DISPLAY	1
• THERE MAY BE FACTORS OTHER THAN THE MISSION CAUSING DEGRADATION	1
• WHAT ARE THE MODULE OPERATING HOURS (CAN I MAKE ADDITIONAL QUERIES?)	1
• IS GPA THE BEST INDEX OF F100 HEALTH?	1

forecasts are provided by both systems. System B uses graphics to depict performance associated forecasted removals.

Figure 16 shows the system ratings. System A is rated as clear with enough information and more effective than current procedures. A larger uncertainty was expressed in System B resulting from the graphical presentation. Figure 17 shows that this uncertainty is manifested by a significant preference for System A. Comments listed in Table 6 reinforce confusion concerning the bargraph format.

The miscellaneous question responses validate the spread in perception of the bargraph effectiveness. This response can be explained by emphasizing the wide disparity in survey participant experience and exposure to graphical evaluation products of this type. It was overwhelmingly asserted that this functional capability is important to base level management.

2.7 Question G - OCM Team

The secenario explores information requirements for OCM depot evaluation of required maintenance procedures. A single display system was utilized to evaluate the capability that indexed data offers for this type of maintenance procedure.

The ratings shown in Figure 18 indicate the capabilities identified in the system are clear, contain sufficient data, and are more effective than procedures in place.

Figure 19 presents the responses to miscellaneous questions. These are summarized below:

(1) Inverse highlighting is rated extremely effective.

(2) Unlike other bargraph representations, GPA snapshot bargraphs are rated effective.

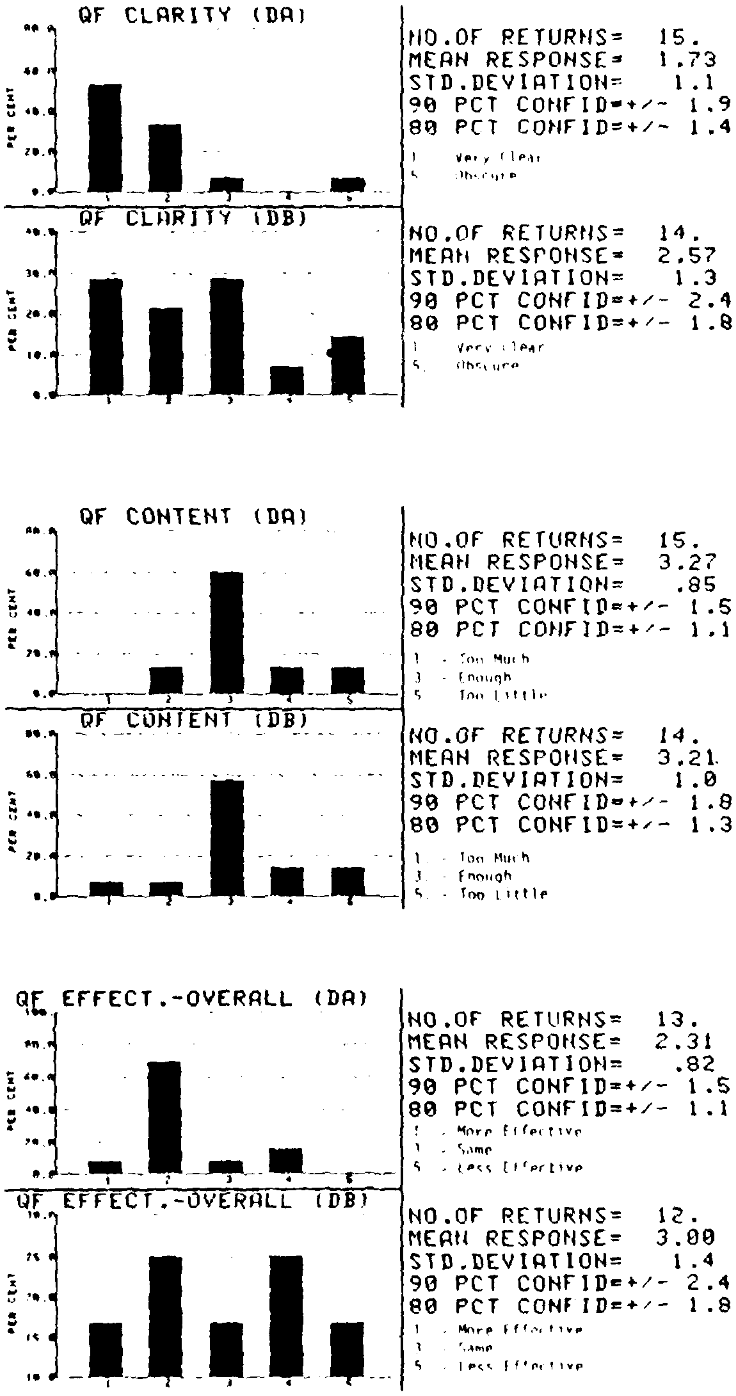


Figure 16 Display System Rating Response

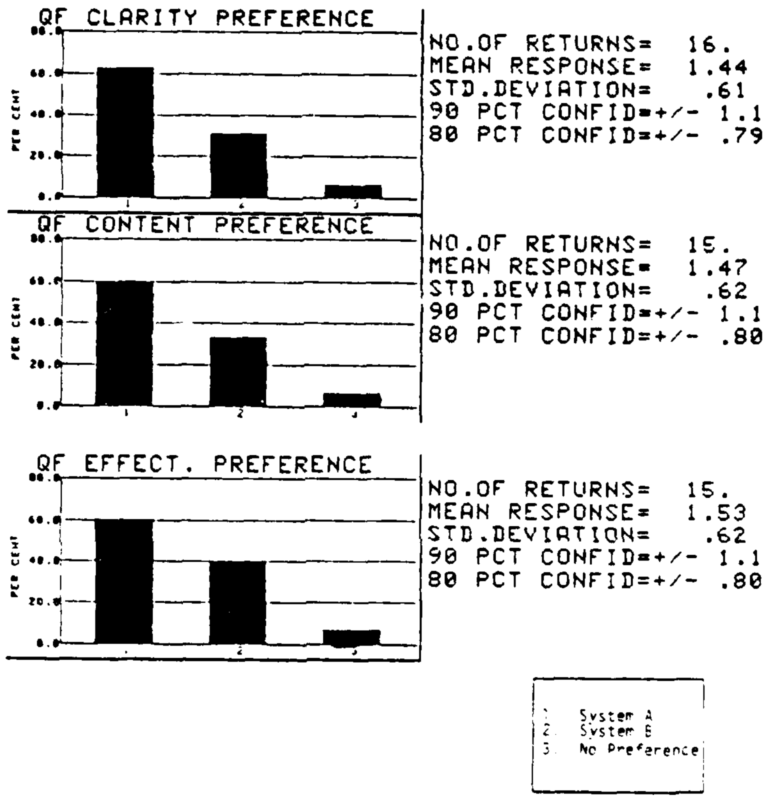


Figure 17 Display System Preference

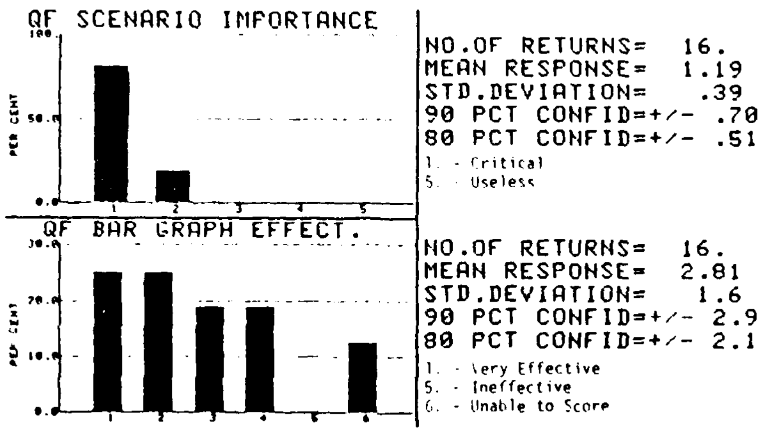
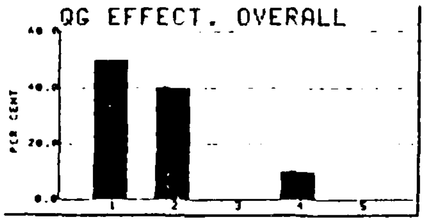
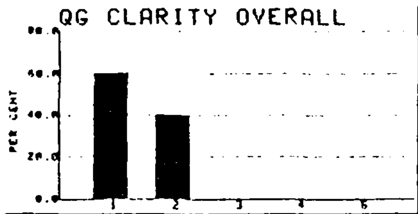


Figure 18 Response to Miscellaneous Questions



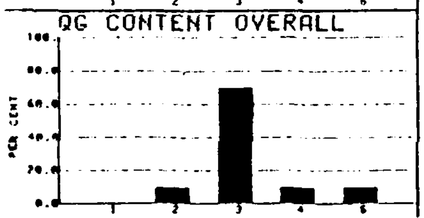
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.70
STD.DEVIATION= .90
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.2

1. - More Effective
3. - Same
5. - Less Effective



NO.OF RETURNS= 10.
MEAN RESPONSE= 1.40
STD.DEVIATION= .49
90 PCT CONFID=+/- .88
80 PCT CONFID=+/- .64

1. - Very Clear
5. - Obscure



NO.OF RETURNS= 10.
MEAN RESPONSE= 3.20
STD.DEVIATION= .75
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .97

1. - Too Much
3. - Enough
5. - Too Little

Figure 19 Display System Rating Response

(3) Trending GPA results are viewed as helpful.

(4) Vibration history plots are perceived as very helpful.

(5) All respondents indicated that SOAP results are required for OCM.

(6) All respondents indicated the effectiveness of SOAP particulate rate. This conclusion was not accepted by the task force.

(7) Maintenance history records were overwhelmingly believed to be effective.

(8) Data products were desired in graphics and hard copy.

(9) There is no clear cut preference for the full life usage status (G337) over screened parts replacement products.

(10) The entire list of outstanding TCTO's was preferred.

Comments are included in Table 7.

2.8 Question H - Depot Maintenance Forecasts

The scenario addresses depot return forecasting using usage and performance records. A single system illustrates an interactive form input and tabular data product.

Figure 20 shows that the system was rated very clear but without sufficient information. Significantly, respondents perceived the system to be more effective than the current procedure. This indicates a general lack of confidence by the respondents in current information management methods to address this function. Table 8 lists the comments. A two year forecast period was reenforced by the task force.

Figure 21 shows the miscellaneous question responses. Monthly forecasts rated as extremely valuable. Accuracy level preference is between 80% and 90%. Removal cause was selected as an additional data item by a majority of the respondents.

Table 6

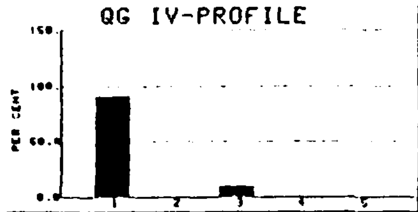
Maintenance Forecast - User Survey

COMMENT	FREQUENCY
• PERFORMANCE TRENDS AND ACCURATE PROGNOSTICATION ARE KEYS TO OCM	1
• CONSIDER ESTABLISHMENT OF WATCH STATUS FOR MONITORING ENGINES (IT SUPPORTS FORECAST)	3
• SHOW BOTH TIME/CYCLE AND FAILURE REMOVALS ON SAME SCREEN OR CROSS-REFERENCE THEM	1
• BAR GRAPH CONFUSING - LESS EFFECTIVE	6
• PREFER BAR GRAPH	1
• INCLUDE FAILURE REASONS	1
• GPA TREND RATE MORE IMPORTANT THAN DELTA	1
• GIVE EXPECTED EOT UNTIL REMOVAL	1
• HOW WERE GPA FAILURE PROJECTIONS DERIVED?	1

Table 7

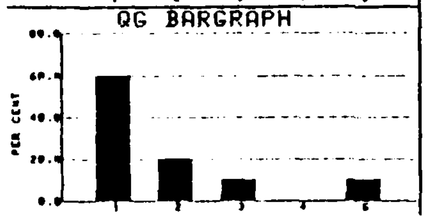
OCM TEAM - Survey Comments

COMMENT	FREQUENCY
• HARD COPY OF DISPLAYS WOULD BE BENEFICIAL	1
• DATA DISPLAYS SHOULD ALSO BE AVAILABLE AT BASE LEVEL	1
• INCLUDE LEVELS FOR VIBRATION, SOAP AND OVERTEMP ON PROFILE	1
• INDICATE DATE OF LAST REPAIR AT SA-ALC	1
• DISPLAY MORE DIAGNOSTIC DATA FOR OVERTEMP EVENT	1



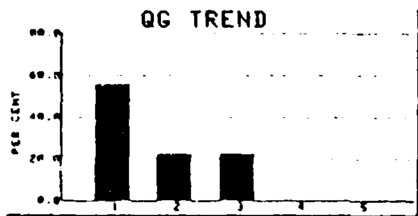
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.20
STD.DEVIATION= .60
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .78
1. - Very Effective
5. - Ineffective

HIGHLIGHTS

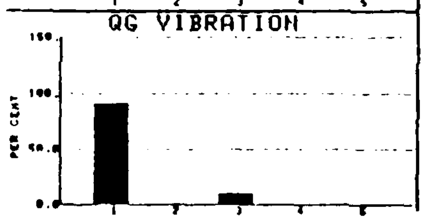


NO.OF RETURNS= 10.
MEAN RESPONSE= 1.80
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6
1. - Very Effective
5. - Ineffective

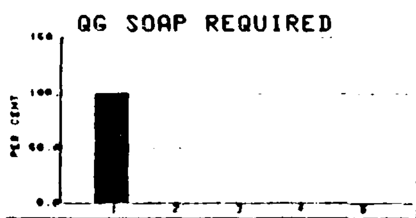
GPA



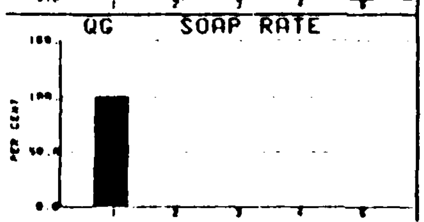
NO.OF RETURNS= 9.
MEAN RESPONSE= 1.67
STD.DEVIATION= .82
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1
1 - Very Helpful
5. - Useless



NO.OF RETURNS= 10.
MEAN RESPONSE= 1.20
STD.DEVIATION= .60
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .78
1. - Very Helpful
5. - Useless

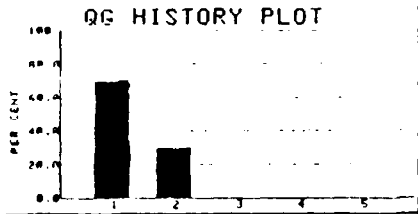


NO.OF RETURNS= 10.
MEAN RESPONSE= 1.00
STD.DEVIATION= 0.
90 PCT CONFID=+/-0.
80 PCT CONFID=+/-0.
1 - Very Essential
5 - Not Required

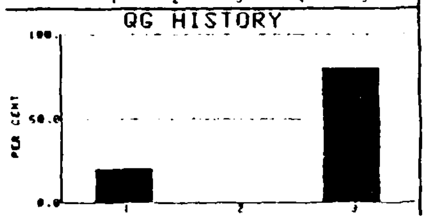


NO.OF RETURNS= 10.
MEAN RESPONSE= 1.00
STD.DEVIATION= 0.
90 PCT CONFID=+/-0.
80 PCT CONFID=+/-0.
1 - Very Effective
5 - Ineffective

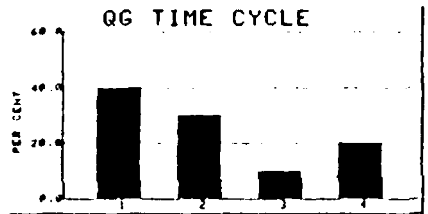
Figure 20 Response to Miscellaneous Questions



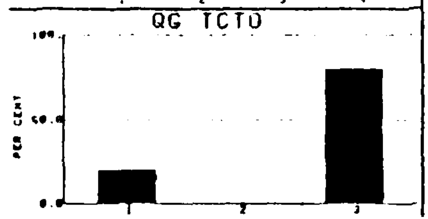
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.30
STD.DEVIATION= .46
90 PCT CONFID=+/- .82
80 PCT CONFID=+/- .60
1. - Very Effective
5 - Ineffective



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.60
STD.DEVIATION= .80
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0
1. - CRT Display
2 - Manual Records Only
3. - CRT Display & Manual Records

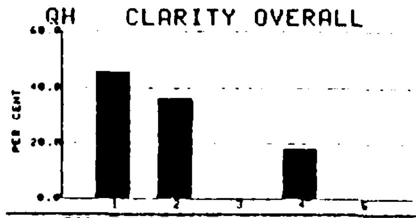


NO.OF RETURNS= 10.
MEAN RESPONSE= 2.10
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.5
1. - CRT Display-Automatic Screening
2 - G337 Products
3. - CRT Display & G337
4 - G337 With Screened Components IV



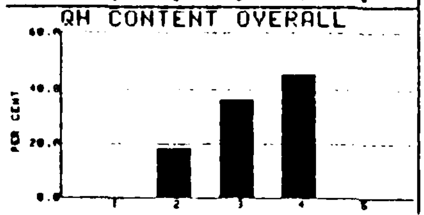
NO.OF RETURNS= 10.
MEAN RESPONSE= 2.60
STD.DEVIATION= .80
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0
1. - Entire List
2. - CRT Display of Selected TCTOs
3. - CRT Display of Entire List With IV

Figure 20 Response to Miscellaneous Questions (Continued)



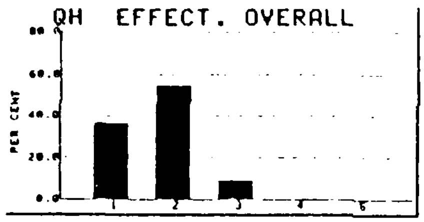
NO.OF RETURNS= 11.
MEAN RESPONSE= 1.91
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 1.9
80 PCT CONFID=+/- 1.4

1. - Very Clear
5. - Obscure



NO.OF RETURNS= 11.
MEAN RESPONSE= 3.27
STD.DEVIATION= .75
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .97

1. - Too Much
3. - Enough
5. - Too Little



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.73
STD.DEVIATION= .62
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .80

1. - More Effective
3. - Same
5. - Less Effective

Figure 21 Display System Rating Response

2.9 Question I - Multiple Base Deployment

This scenario addresses command level requirements for a multiple base, short term, tactical deployment. Both displays utilize an automated form type entry. Display System A uses a lower density format. System B uses paged information and includes usage and performance data on selected engines.

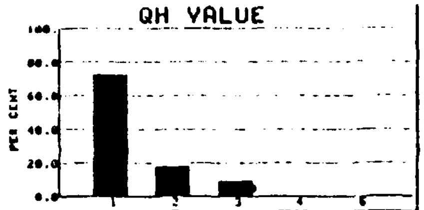
Figure 22 shows the rating responses for each system. The format of display system A was rated clear but lacked sufficient information. System B was acceptable in clarity and contained sufficient information. Table 9 lists the comments from respondents. A significant portion has doubts concerning the validity of this scenario; hence, interpretation of the functional aspects of the responses are not possible. Figure 24 indicates that System A is preferred for clarity but the information content is less preferrable than System B.

Figure 23 shows the results of the questions pertaining to the value of the concept and the acceptance of this functional capability. A strongly mixed reaction is observed indicating some negative preference among respondents and confusion over methods and calculation techniques. The task force indicated that this type of capability would be useful at the base level; however, maintanence personnel should utilize sorting capabilities of MIMS to screen engines for deployment.

2.10 Question J - TCTO Assessment

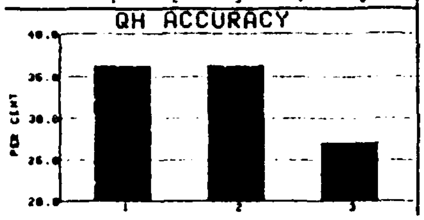
This scenario addresses command level management of TCTO impact and assessment of fleetwide maintanence requirements. Display System A presents tabular grouping formats and System B uses bargraphs.

Both systems were rated in almost the same way (Figure 25). Clarity was very acceptable, content was insufficient, to address the



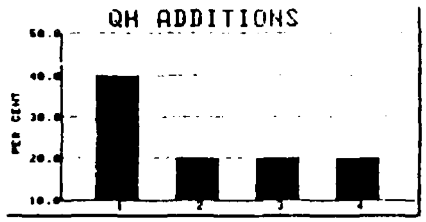
NO.OF RETURNS= 11.
MEAN RESPONSE= 1.36
STD.DEVIATION= .64
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .84

1 - Extremely Valuable
5 - Worthless



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.91
STD.DEVIATION= .79
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0

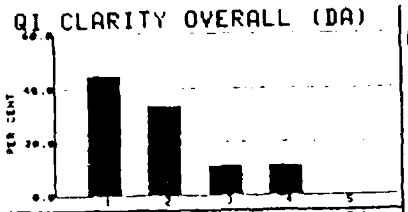
1. - Correct more than 90% of the time
2. - Correct more than 80% of the time
3. - Correct more than 70% of the time



NO.OF RETURNS= 5.
MEAN RESPONSE= 2.20
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.1
80 PCT CONFID=+/- 1.5

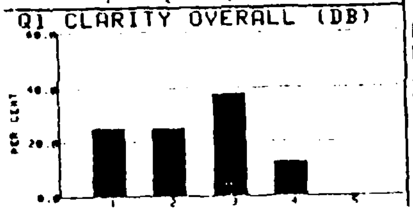
1. - Cause of Failure
2. - TOT
3. - LCF
4 - TAMP

Figure 22 Response to Miscellaneous Questions



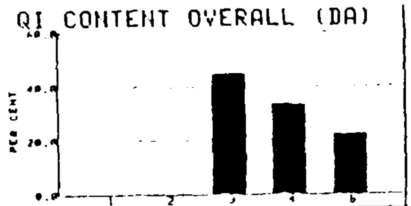
NO.OF RETURNS= 9.
MEAN RESPONSE= 1.89
STD.DEVIATION= .99
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3

1 - Very Clear
5 - Obscure



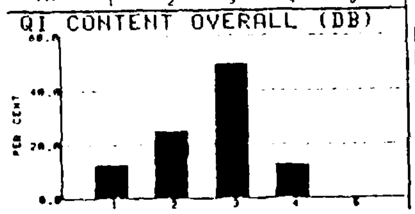
NO.OF RETURNS= 8.
MEAN RESPONSE= 2.38
STD.DEVIATION= .99
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3

1 - Very Clear
5 - Obscure



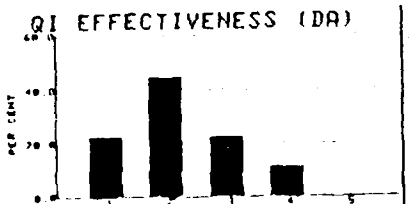
NO.OF RETURNS= 9.
MEAN RESPONSE= 3.78
STD.DEVIATION= .79
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0

1 - Too Much
3 - Enough
5 - Too Little



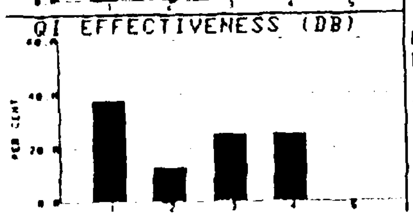
NO.OF RETURNS= 8.
MEAN RESPONSE= 2.63
STD.DEVIATION= .86
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1

1 - Too Much
3 - Enough
5 - Too Little



NO.OF RETURNS= 9.
MEAN RESPONSE= 2.22
STD.DEVIATION= .92
90 PCT CONFID=+/- 1.6
80 PCT CONFID=+/- 1.2

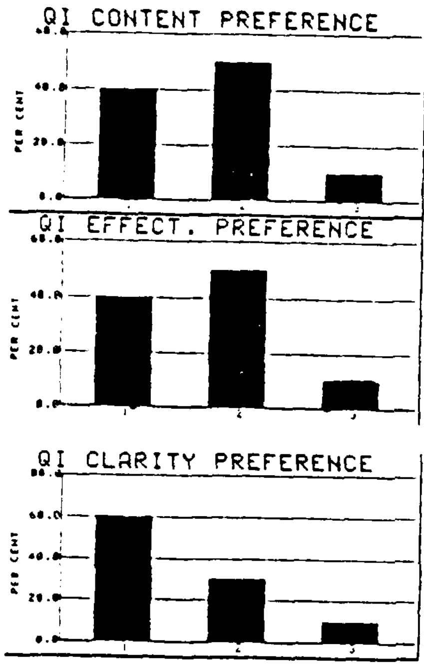
1 - More Effective
3 - Same
5 - Less Effective



NO.OF RETURNS= 8.
MEAN RESPONSE= 2.38
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6

1 - More Effective
3 - Same
5 - Less Effective

Figure 23 Display System Rating Response



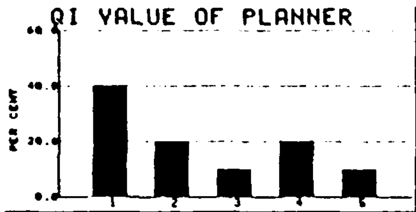
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.70
STD.DEVIATION= .64
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .83

NO.OF RETURNS= 10.
MEAN RESPONSE= 1.70
STD.DEVIATION= .64
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .83

NO.OF RETURNS= 10.
MEAN RESPONSE= 1.50
STD.DEVIATION= .67
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .87

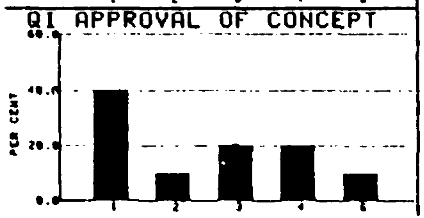
1. System A
2. System B
3. No Preference

Figure 24 Display System Preferences



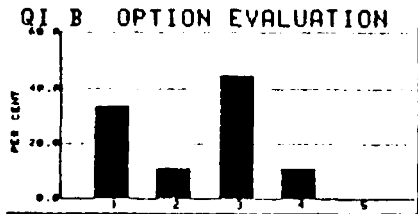
NO.OF RETURNS= 10.
MEAN RESPONSE= 2.40
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.6
80 PCT CONFID=+/- 1.9

1. - Very Valuable
5. - Worthless



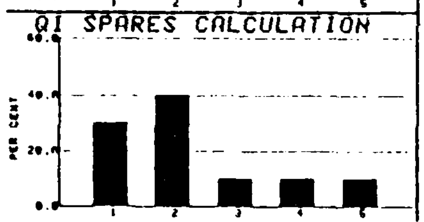
NO.OF RETURNS= 10.
MEAN RESPONSE= 2.50
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.6
80 PCT CONFID=+/- 1.9

1. - Strongly Approve
5. - Strongly Disapprove



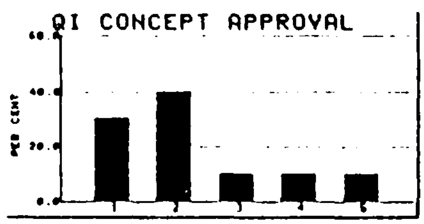
NO.OF RETURNS= 9.
MEAN RESPONSE= 2.33
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 1.9
80 PCT CONFID=+/- 1.4

1. - Very Valuable
5. - Worthless



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.30
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.6

1. - Very Valuable
5. - Worthless



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.30
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.6

1. - Strongly Approve
5. - Strongly Disapprove

Figure 25 Response to Miscellaneous Questions

scenario and effectiveness preference against current procedures was inconclusive. Figure 26 shares that the tabular presentation (System A) was more preferrable than the graphical (System B), especially in the amount of information presented in the product.

Responses to questions are shown in Figure 27 and comments in Table 10. Engine location in the pipeline is rated as important. Split responses in the value of graphics is reflected in the effectiveness rating for the graphical forecast. One comment was received with significant frequency regarding multiple system access to resolve management function. This response can be interpreted as negative reaction to systems in which significant user cross referrencing is required to obtain data items that are matched to a particular functional requirement.

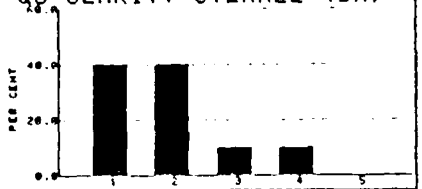
2.11 Question K - Spare Engine Status

This scenario addresses the command level engine manager requirement to monitor spare engine status at a number of remote operating bases in a timely and efficient manner. Both systems present the same tabular data format. System A uses highlighting of data and System B uses classical exception management procedures to flag detected anamolies.

Both systems (Figure 28) were rated clearly understandable. System A was judged more effective than current practices. A significant preference appeared in rating the exception capability. In this small sample, the respondents viewed System B as having insufficient information; however, several felt strongly that it was more effective than current practices. In Figure 29, System A was preferred over system B by respondents.

These responses indicate that, while classical exception management procedures can be used for highlighting problems,

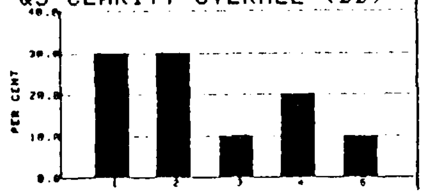
QJ CLARITY OVERALL (DA)



NO.OF RETURNS= 10.
MEAN RESPONSE= 1.90
STD.DEVIATION= .94
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2

1. - Very Clear
5. - Obscure

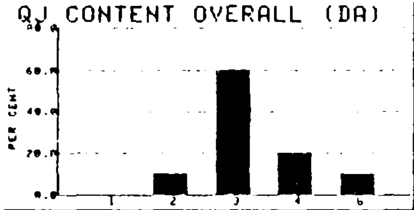
QJ CLARITY OVERALL (DB)



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.50
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.4
80 PCT CONFID=+/- 1.8

1. - Very Clear
5. - Obscure

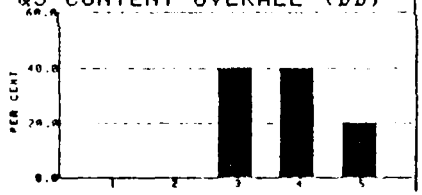
QJ CONTENT OVERALL (DA)



NO.OF RETURNS= 10.
MEAN RESPONSE= 3.30
STD.DEVIATION= .78
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0

1. - Too Much
3. - Enough
5. - Too Little

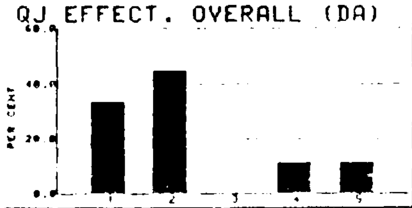
QJ CONTENT OVERALL (DB)



NO.OF RETURNS= 10.
MEAN RESPONSE= 3.80
STD.DEVIATION= .75
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .97

1. - Too Much
3. - Enough
5. - Too Little

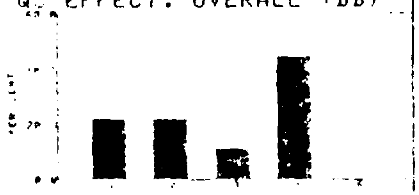
QJ EFFECT. OVERALL (DA)



NO.OF RETURNS= 9.
MEAN RESPONSE= 2.22
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.4
80 PCT CONFID=+/- 1.7

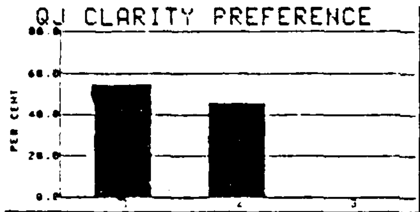
1. - More Effective
3. - Same
5. - Less Effective

QJ EFFECT. OVERALL (DB)

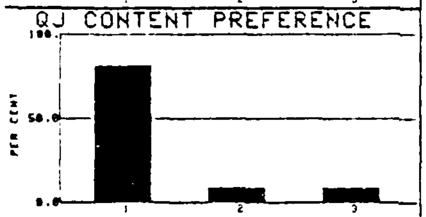


NO.OF RETURNS= 9.
MEAN RESPONSE= 2.78
STD.DEVIATION= 1.2
90 PCT CONFID=+/- 2.2
80 PCT CONFID=+/- 1.6

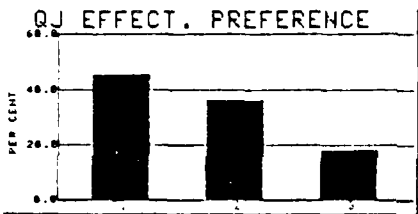
Figure 26. Display System Rating Response



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.45
STD.DEVIATION= .50
90 PCT CONFID=+/- .90
80 PCT CONFID=+/- .65



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.27
STD.DEVIATION= .62
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .80



NO.OF RETURNS= 11.
MEAN RESPONSE= 1.73
STD.DEVIATION= .75
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .97

1. - System A
2. - System B
3. - No Preference

Figure 27 Display System Preferences

Table 8

Maintenance Forecast - Survey Comments

COMMENT	FREQUENCY
• INCLUDE PROBABLE CAUSE OF FAILURE	2
• PROBABILITY OF MODULE RETURN ONLY	1
• REQUIRE AT LEAST 6 MONTH PROJECTION	1
• USE AT BASE LEVEL ALSO	1
• LONGER TERM REMOVAL FORECASTS (2 YRS) REQUIRED TO SUPPORT LOGISTICS MODELS AND PROCUREMENT LEAD TIME	2

Table 9

Multiple Base Deployment - Survey Comments

COMMENT	FREQUENCY
• DEPLOYMENT MAY BE VIABLE AT BASE LEVEL - PROBABLY NOT USEFUL AT COMMAND LEVEL	2
• CAN ALL AIRCRAFT AND SPARES COME FROM ONE BASE?	1
• CERTAIN CONSTRAINTS IMPOSED BY DEPLOYMENT REQUIREMENTS AUTOMATICALLY ELIMINATE SOME AIRCRAFT FAIL NUMBERS (ENGINE HEALTH IS NOT THE ONLY FACTOR)	2
• REQUIRE MORE INFORMATION TO DO PLANNING (TIME FACTORS, HOT TIME, OUTSTANDING TCTO'S)	3
• DISPLAY INDIVIDUAL GPA NOT JOINT	1
• PROVIDE MORE THAN REQUIRED AIRCRAFT FOR SELECTION PURPOSES	1
• CURIOUS HOW AIRCRAFT ARE AUTOMATICALLY SELECTED	1
• DON'T PUT AUTOMATICALLY REPLACE ENGINE, LET THE USER DETERMINE THAT	1

Table 10

QJ - TCTO Assessment - Survey Comments

COMMENT	FREQUENCY
• BAR GRAPH A VIABLE HIGH LEVEL DISPLAY	2
• ADDITIONAL QUERIES REQUIRED TO SOLVE ALL MANAGEMENT PROBLEMS	4
• ACCESS INFORMATION ON NEXT SCHEDULED MAINTENANCE ACTIONS FOR ENGINES CLOSE TO LIMIT	1
• DOES THE DATA BASE INCLUDE INFORMATION INTRANSIT TO DEPOT	1
• CONCERN WITH FORECAST LOGIC	1

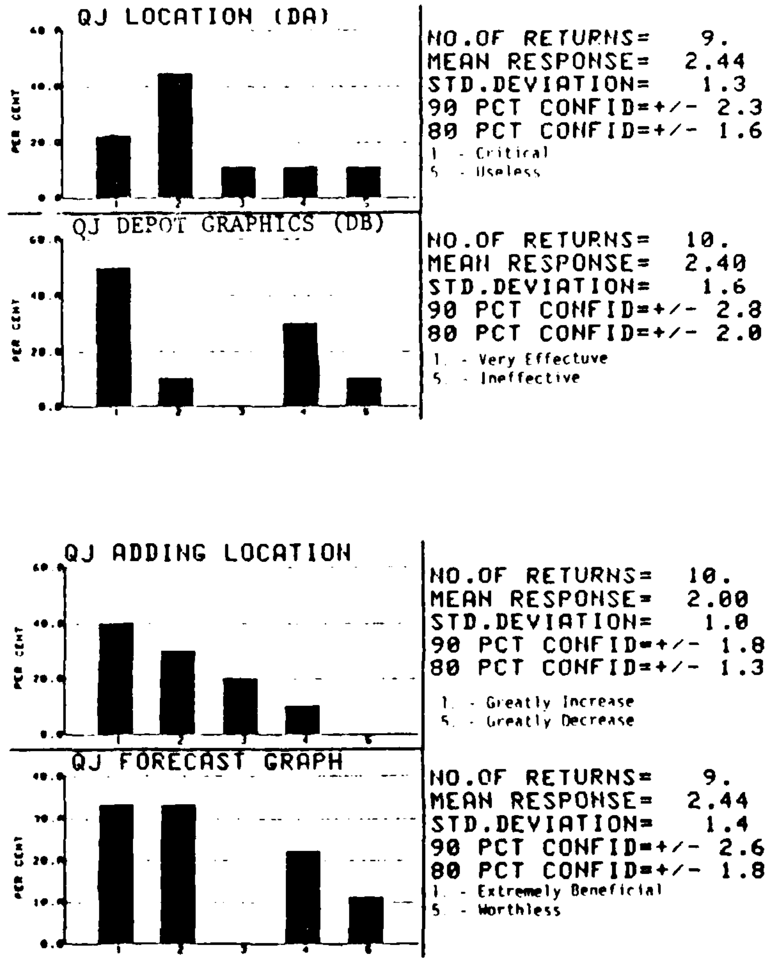
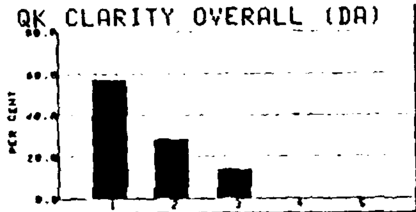
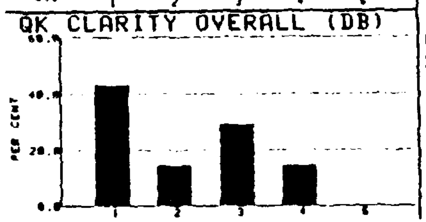


Figure 28 Response to Miscellaneous Questions



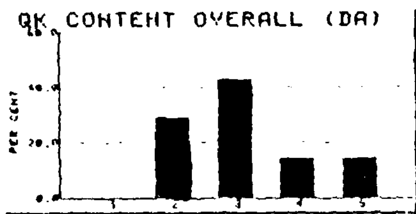
NO.OF RETURNS= 7.
MEAN RESPONSE= 1.57
STD.DEVIATION= .73
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .95

1. - Very Clear
5. - Obscure



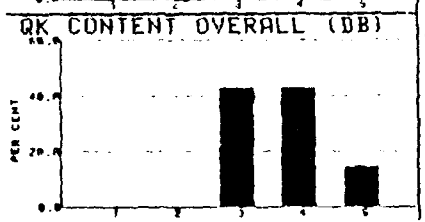
NO.OF RETURNS= 7.
MEAN RESPONSE= 2.14
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.5

1. - Very Clear
5. - Obscure



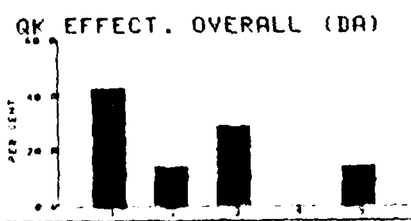
NO.OF RETURNS= 7.
MEAN RESPONSE= 3.14
STD.DEVIATION= .99
90 PCT CONFID=+/- 1.8
80 PCT CONFID=+/- 1.3

1. - Too Much
3. - Enough
5. - Too Little



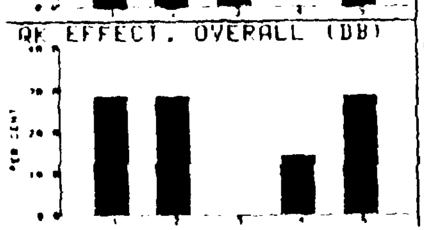
NO.OF RETURNS= 7.
MEAN RESPONSE= 3.71
STD.DEVIATION= .70
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .91

1 - Too Much
3 - Enough
5 - Too Little



NO.OF RETURNS= 7.
MEAN RESPONSE= 2.29
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.5
80 PCT CONFID=+/- 1.8

1 More Effective
3 Same
5 Less Effective



NO.OF RETURNS= 7.
MEAN RESPONSE= 2.86
STD.DEVIATION= 1.6
90 PCT CONFID=+/- 3.0
80 PCT CONFID=+/- 2.1

1 More Effective
3 Same
5 Less Effective

Figure 29 Display System Rating Response

highlighting and summary methods may be more acceptable to the management personnel because there is no perception of missing data. These responses are reinforced by miscellaneous question responses (Figure 30) and comments in Table 11.

III. CUMULATIVE SURVEY RESPONSES

Survey responses to data item categories included in several questions are summarized in this section. Figures 32-37 present these results. The results detailed in Chapter III were based on these tallied responses.

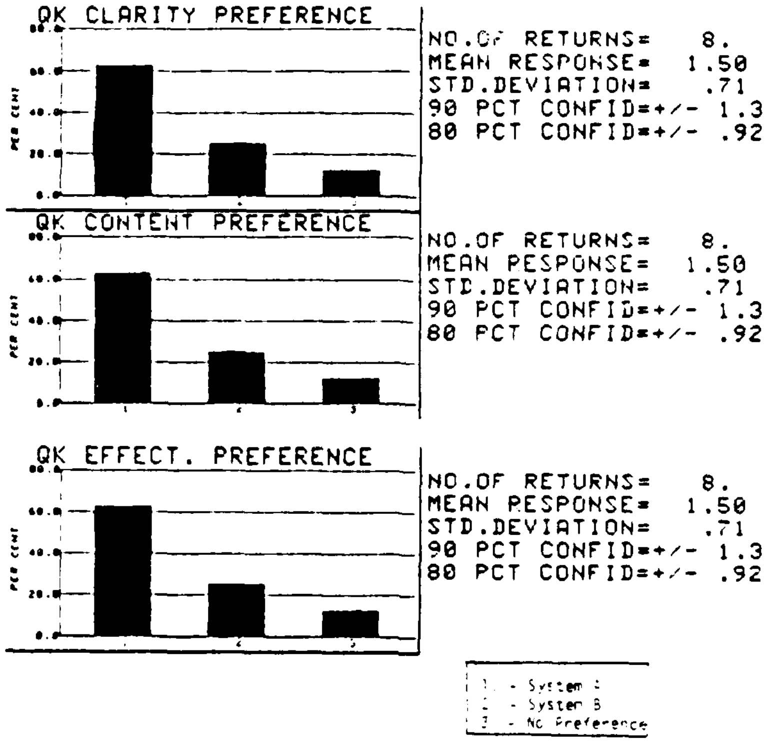


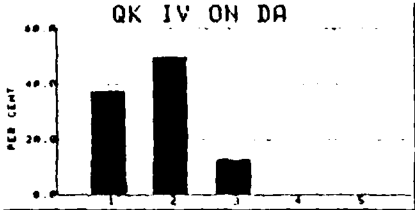
Figure 30 Display System Preferences

Table 11

QK - Spare Engine Status - Survey Comments

COMMENT	FREQUENCY
• DEFINE ADDITIONAL DISPLAYS TO IDENTIFY THE PARTS PROBLEMS FOR ENMCS	2
• FURTHER DEFINE PIPELINE SEGMENTS	2
• DEFINE EXCEPTION REPORTING LOGIC BASED ON PIPELINE STANDARDS	2
• ELIMINATE %/REPLACE WITH AUTHORIZED LEVEL AND NUMBER ON HAND	4
• ADD % COMPLETE CLASSIFICATION	1

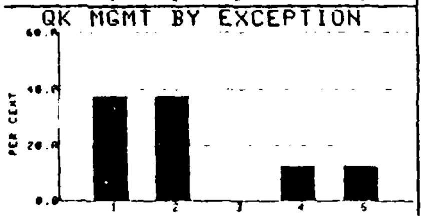
QK IV ON DA



NO.OF RETURNS= 8.
MEAN RESPONSE= 1.75
STD.DEVIATION= .66
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .86

1. - Very Effective
5. - Ineffective

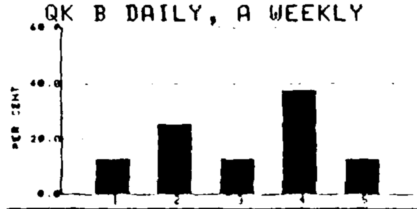
QK MGMT BY EXCEPTION



NO.OF RETURNS= 8.
MEAN RESPONSE= 2.25
STD.DEVIATION= 1.4
90 PCT CONFID=+/- 2.5
80 PCT CONFID=+/- 1.8

1. - Very Effective
5. - Ineffective

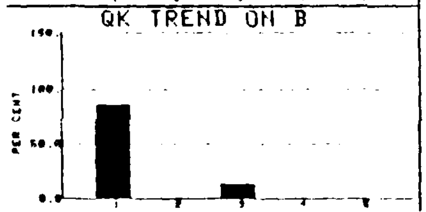
QK B DAILY, A WEEKLY



NO.OF RETURNS= 8.
MEAN RESPONSE= 3.13
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.6

1. - More Effective
3 - Same
5 - Less Effective

QK TREND ON B



NO.OF RETURNS= 7.
MEAN RESPONSE= 1.29
STD.DEVIATION= .70
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .91

1 - Very Valuable
5 Worthless

Figure 31 Response to Miscellaneous Questions

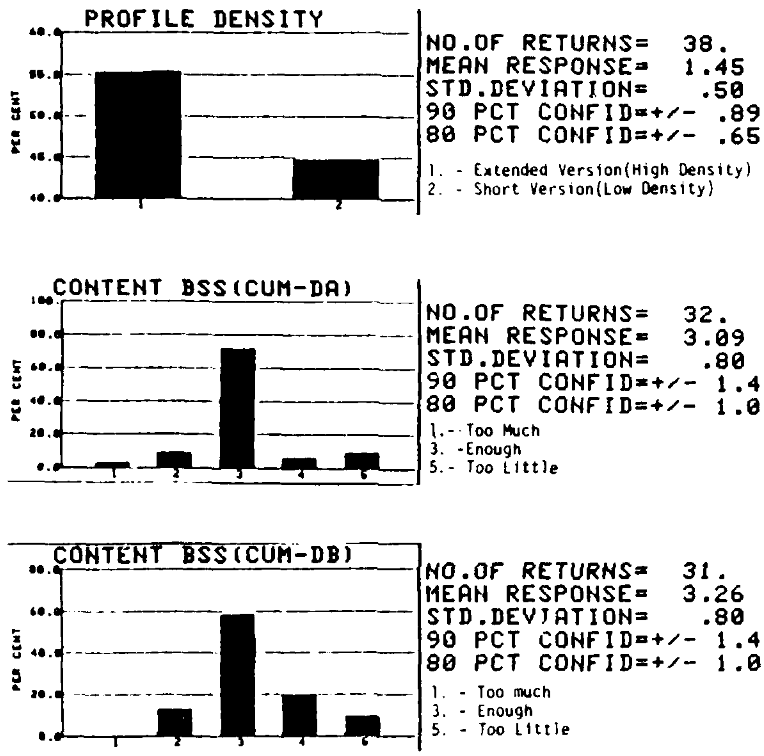
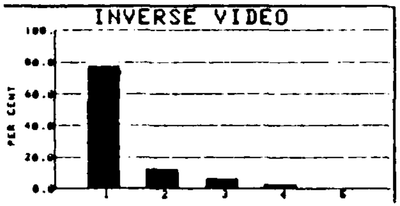
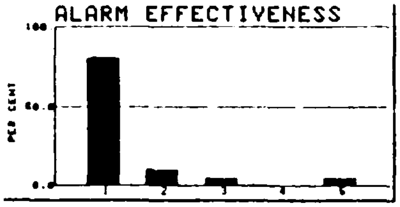


Figure 32 Profile and Status Summary Presentation Responses



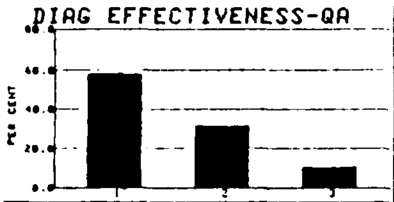
NO.OF RETURNS= 31.
MEAN RESPONSE= 1.35
STD.DEVIATION= .74
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .97

1. - Very Effective
5. - Ineffective



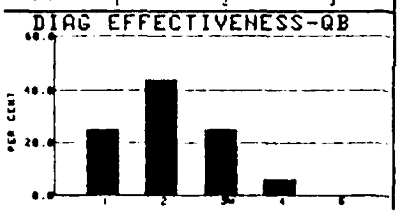
NO.OF RETURNS= 20.
MEAN RESPONSE= 1.40
STD.DEVIATION= .97
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.3

1. - Very Effective
5. - Ineffective



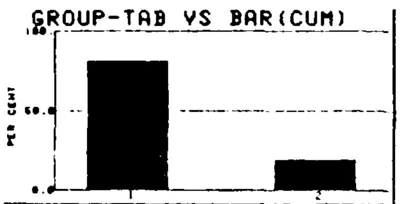
NO.OF RETURNS= 19.
MEAN RESPONSE= 1.53
STD.DEVIATION= .68
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .88

1. - Adequate
2. - Inadequate
3. - Unable to Score



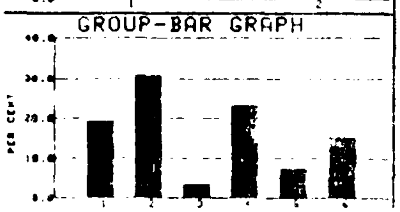
NO.OF RETURNS= 16.
MEAN RESPONSE= 2.13
STD.DEVIATION= .86
90 PCT CONFID=+/- 1.5
80 PCT CONFID=+/- 1.1

1. - Very Effective
5. - Ineffective



NO.OF RETURNS= 26.
MEAN RESPONSE= 1.19
STD.DEVIATION= .39
90 PCT CONFID=+/- .71
80 PCT CONFID=+/- .51

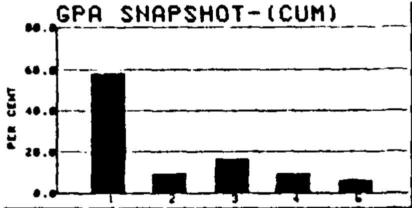
1. - Tabular Preferred
2. - Bargraph Preferred



NO.OF RETURNS= 26.
MEAN RESPONSE= 3.15
STD.DEVIATION= 1.7
90 PCT CONFID=+/- 3.1
80 PCT CONFID=+/- 2.2

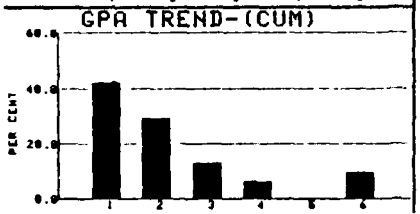
1. - Very Effective
5. - Ineffective
6. - Unable to Score

Figure 75. Data Access Display
[illegible]



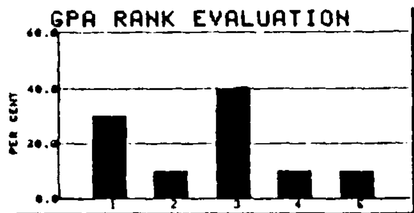
NO.OF RETURNS= 31.
MEAN RESPONSE= 1.97
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.4
80 PCT CONFID=+/- 1.7

1. Very Effective
5. Ineffective



NO.OF RETURNS= 31.
MEAN RESPONSE= 2.23
STD.DEVIATION= 1.5
90 PCT CONFID=+/- 2.7
80 PCT CONFID=+/- 2.0

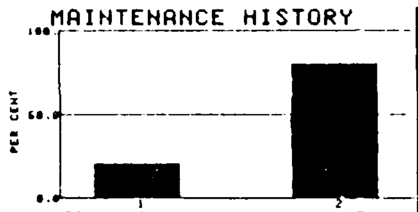
1. Very Effective
5. Ineffective



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.60
STD.DEVIATION= 1.3
90 PCT CONFID=+/- 2.3
80 PCT CONFID=+/- 1.7

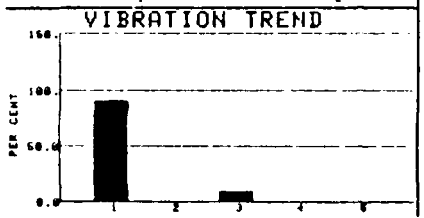
1. - Very Valuable
5. - Worthless
6. - Unable to Score

Figure 34 Performance Rating
[illegible]



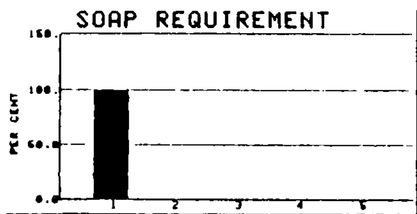
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.80
STD.DEVIATION= .40
90 PCT CONFID=+/- .72
80 PCT CONFID=+/- .52

1. - CRT Display
2. - CRT Display & Manual Records



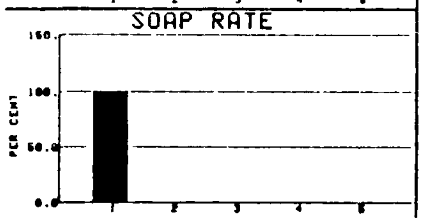
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.20
STD.DEVIATION= .60
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .78

1. - Very Useful
5. - Useless



NO.OF RETURNS= 10.
MEAN RESPONSE= 1.00
STD.DEVIATION= 0.
90 PCT CONFID=+/-0.
80 PCT CONFID=+/-0.

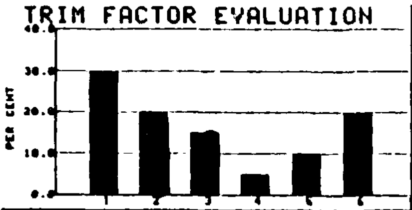
1. - Very Essential
5. - Not Required



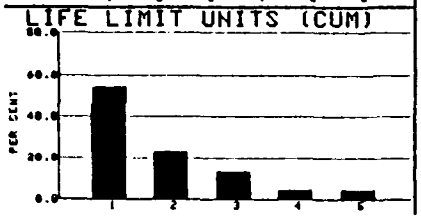
NO.OF RETURNS= 10.
MEAN RESPONSE= 1.00
STD.DEVIATION= 0.
90 PCT CONFID=+/-0.
80 PCT CONFID=+/-0.

1. - Very Effective
5. - Ineffective

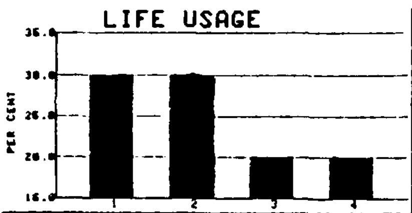
Figure 35 Integrated Data Source Evaluation



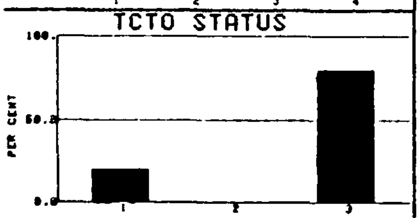
NO.OF RETURNS= 20.
MEAN RESPONSE= 3.05
STD.DEVIATION= 1.9
90 PCT CONFID=+/- 3.4
80 PCT CONFID=+/- 2.5
1. - Extremely Essential
5. - Worthless
6. - Unable to Score



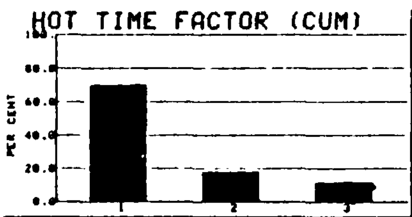
NO.OF RETURNS= 22.
MEAN RESPONSE= 1.82
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.4
1. - 100 Hours
2. - Component Closest to Limit
3. - Flexible
4. - 50 Hours
5. - 200 Hours



NO.OF RETURNS= 10.
MEAN RESPONSE= 2.30
STD.DEVIATION= 1.1
90 PCT CONFID=+/- 2.0
80 PCT CONFID=+/- 1.4
1. -CRT Display-Automatic Screening
2. -G337 Products
3. -CRT Display & G337
4. -G337 With Screened Components IV

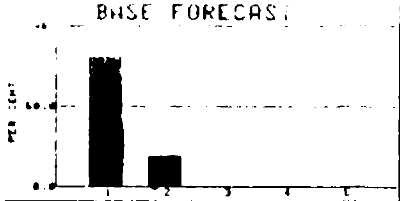


NO.OF RETURNS= 10.
MEAN RESPONSE= 2.60
STD.DEVIATION= .80
90 PCT CONFID=+/- 1.4
30 PCT CONFID=+/- 1.0
1. -Entire List
2. -CRT Display of Selected TCTOs
3. -CRT Display of Entire List With IV



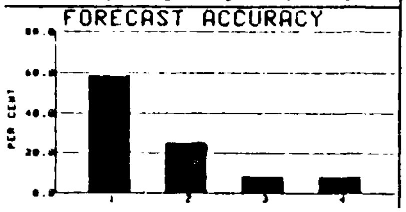
NO.OF RETURNS= 50.
MEAN RESPONSE= 1.42
STD.DEVIATION= .70
90 PCT CONFID=+/- 1.3
80 PCT CONFID=+/- .90
1. - Hours
2. - Percent
3. - Both

Figure 36 Life Usage Assessment Evaluation



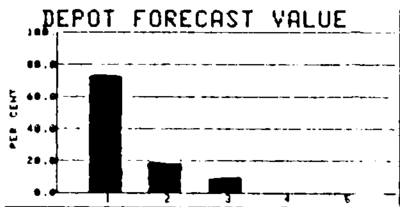
NO.OF RETURNS= 16.
MEAN RESPONSE= 1.19
STD.DEVIATION= .39
90 PCT CONFID=+/- .70
80 PCT CONFID=+/- .51

1 - Critical
5 - Useless



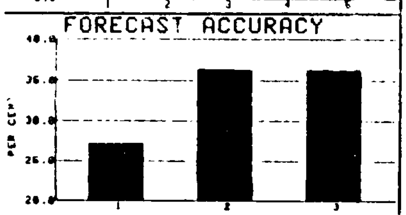
NO.OF RETURNS= 12.
MEAN RESPONSE= 1.67
STD.DEVIATION= .94
90 PCT CONFID=+/- 1.7
80 PCT CONFID=+/- 1.2

1.- 80%
2.- 90%
3.- 95%
4.- 100%



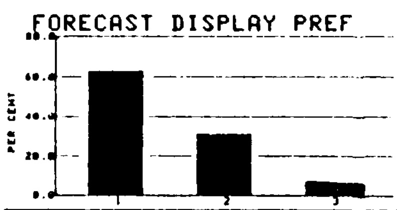
NO.OF RETURNS= 11.
MEAN RESPONSE= 1.36
STD.DEVIATION= .64
90 PCT CONFID=+/- 1.2
80 PCT CONFID=+/- .84

- Extremely Valuable
- orthless



NO.OF RETURNS= 11.
MEAN RESPONSE= 2.09
STD.DEVIATION= .79
90 PCT CONFID=+/- 1.4
80 PCT CONFID=+/- 1.0

1. - 80%
2. - 90%
3. - No Opinion



NO.OF RETURNS= 16.
MEAN RESPONSE= 1.44
STD.DEVIATION= .61
90 PCT CONFID=+/- 1.1
80 PCT CONFID=+/- .79

1. - Tabular
2. - Bargraph

Figure 37 Forecast Evaluation

APPENDIX D
TASK FORCE REVIEW TRANSCRIPTS

I. INTRODUCTION

A critical element of the Phase I study effort was the task force review of the survey results and the prototype system requirements definition. This meeting was held at Wright-Patterson Air Force Base, Ohio, on 6-7 June 1979. Participants in the task force were chosen from among the survey respondents and from personal interviews as a cross section of expertise representing base, depot, MAJCOM, and AFLC organizations. This appendix presents edited transcripts from that meeting which include critical commentary and insights into Air Force operational information requirements.

II. ORGANIZATION OF TRANSCRIPTS

The task force agenda is shown in Table 1. The survey formats and scenarios were introduced and the results reviewed. The displays selected during the survey process were then used as the basis for the remaining discussion. The objective of this dialogue was to establish a consensus of opinion on data requirements and information management concepts for integration of automated TEMS-acquired data into the O&S process.

The discussions were wide ranging and frank concerning the current status and desirable improvements. The edited comments are indexed in the margin according to requirement and topic to facilitate easy reference. The column indexes are correlated to major elements of the requirement definition in Table 2 and cross-referenced to transcript pagination in Table 3. The discussions in the transcript cover base level and depot information requirements

Table 1

Task Force Review Agenda

6 JUNE 1979	
8:15	Introduction
8:30	Task Force Objectives/Background
8:45	Summary of Survey Results
9:30	System Overview
10:00	Base Level Prototype System Capabilities
1:00	Depot Prototype System Capabilities
2:00	Command Level Prototype System Capabilities
2:45	Session Review
7 JUNE 1979	
8:30	Review First Session
9:00	Summary of Results
9:30	Presentation Final System Design
11:00	Discussion

TABLE 2

Correlation of Major Topics with Index Symbols

CATEGORY/TOPICS	INDEX SYMBOL
SYSTEM OVERVIEW	
- Introductory Remarks	In
- Goals of System	Go
MAINTENANCE MANAGEMENT PROCESS	
- Management Decision Process	Md
- Deployment	De
- On-Condition Maintenance	Oc
- Opportunistic Maintenance	Om
EXCEPTION REPORTING	
- Data Alarms, Exceptions	Al
- Management By Exception	Me
- Watch Status	Ws
DATA/INFORMATION ITEMS	
- Diagnostic Messages	Dm
- Historical Data Requirements	Hd
- Maintenance History Requirements	Hm
- Gas Path Average	Ga
- Life Usage Messages	Lu
- SOAP	So
- Supply Considerations	Su
- Tracking Modules	Tk
DATA DISPLAYS/FORMAT	
- Base Status Summary	Bs
- Correlation	Co
- Data Format	Df
- Engine Profile	Ep
- Forecast	Fo
- Trending	Tr
DATA ACCESS/INQUIRY	
- Data Access Methods	Da
- Grouping Capabilities	Gr
- Ranking Capabilities	Ra
SYSTEM ARCHITECTURE	
- System Architecture	Ar
- Base Level Processor Requirements	Ba
- Depot Requirements	Dp
- Supply Considerations	Su
DATA ACQUISITION/INPUT	
- Age of Data	Ad
- Base Level Reporting	Br
- Flying Schedule	Fs
- Maintenance Scheduling/Reporting	Ms
- Sensor Reliability/Accuracy	Se
- Comments on TEMS	Te

TABLE 3.
Cross Reference of
Index Sequence to Appendix Pagination

SYMBOL	DESCRIPTION	CROSS-REFERENCE
Ad	Age of Date	9,36
Al	Data Alarms, Exceptions	13
Ar	System Architecture	9,83,95
Ba	Base Level Processor Architecture	9,15,62,81
Br	Base Level Reporting	[illegible]
Bs	Base Status Summary	[illegible]
Co	Correlations	37
Da	Data Access Methods	[illegible],22-23,25,29,35,37,39,42,49,51,[illegible]
De	Deployment	66-69
Df	Data Format	[illegible],25,44,51,53,[illegible]
Dm	Diagnostic Messages	14,22,27,29,[illegible],36
Dp	Depot Requirements	83-90
Ep	Engine Profile	20-2[illegible]
Fo	Forecasting	46,69-75, 79-[illegible]
Fs	Flying Schedule	19,56, [illegible]-92
Ga	Gas Path Average	10,25,31,44,47,51,72
Go	Goals of System	[illegible]
Gr	Grouping Capabilities	[illegible]
Hd	Historical Data Requirements	[illegible]
Hm	Maintenance History Requirements	93,95,[illegible]
In	Introductory Remarks	5
Lu	Life Usage Messages	41,42,51,61
Md	Management Decision Process	[illegible],52,62,64,[illegible]
Me	Management By Exception	24
Ms	Maintenance Scheduling Reporting	14,16-17,[illegible],42,56,[illegible],64
Oc	On-Condition Maintenance	[illegible]
Om	Opportunistic Maintenance	46
Ra	Ranking Capabilities	56-6[illegible]
Se	Sensor Reliability/Accuracy	[illegible]
So	Soap	49
Su	Supply Consideration	62-64
Te	Comments on TEMS	12,26,[illegible]
Tr	Trending	[illegible]
Tm	Tracking Modules	[illegible]
Ws	[illegible] Status	[illegible]

for on-condition maintenance support. Display references are included as figures.

III. PARTICIPANTS

The task force consisted of participants with extensive and wide ranging experience in Air Force engine maintenance, support and logistics at base, depot, command and AFLC levels. Table 4 lists the symbols used to key speakers' comments and cross-references the speakers' expertise and organization.

IV. TASK FORCE TRANSCRIPTS

4.1 Introduction

M: The philosophy of using displays as a means for specifying system requirements was used with the survey. What we were looking for with the displays was an identification of user requirements; based on these user requirements, to drive the specifications of the system requirements. Usually when systems are designed, they go backwards, i.e. they look at the system requirements first, then they force those into the user requirements, and then they generate displays of information. It is hoped that our approach will improve the final output from an automated turbine engine monitoring system, and impact the implementation of the system within the Air Force by integrating information that you'll be giving us today into the design phase.

One of the first concepts in automatically acquiring a large quantity of performance data is the need to reduce it to a concise, usable parameter. One approach is gas path analysis. What you want is the output of the system to be consistent with how the Air Force performs maintenance and performs logistics analysis.

Table 4. Task Force Participant Background and Reference Symbols

TRANSCRIPT SYMBOL	CURRENT ASSIGNMENT		EXPERIENCE PROFILE
B1	BASE	NCO	Base level trouble-shooter with over 20 years experience in all aspects of distance engine maintenance management.
B2	BASE	NCO	Propulsion specialist on F100 maintenance management with recent AGS experience.
B3	BASE	NCO	Propulsion maintenance management with significant prior engine experience, recently associated with F100 CRS.
D1	DEPOT	NCO	Depot-level trouble-shooter with extensive experience at levels of engine maintenance.
D2	DEPOT	CO	TEM Manager with experience in engine and airframe maintenance and support.
D3	DEPOT	CIV	Maintenance engineer and support specialist for various engines.
C1	COMMAND	NCO	TAC liaison for all TEMS programs with extensive experience, engine support and diagnostic experience.
C2	COMMAND	CO	Maintenance officer in TAC for fighter support and is currently TAC branch manager for automatic diagnostic system evaluation.
L1	AFLC	CO	Program management for automatic TEMS in logistics command.
L2	AFLC	CIV	Logistics and actuarial system specialist.
A1	AFWAL	CIV	Advanced development program management for engine diagnostics.
M	SCI(Vt)	CIV	Task Force Moderators

Looking at GPA, you realize early on that in using it and making it a viable parameter to help direct the maintenance, you have to integrate it with some of the other standard factors such as time, cycles, SOAP, vibration, and others. To ultimately integrate the system you need a well-developed plan so that it can be implemented at all levels in the Air Force. We're looking primarily at what information is needed, who is the user, what is the format, how should the data base be organized, and what kind of access
Df the user will have. What we want is to identify those pieces of information normally needed to approach certain maintenance decisions, management problems, and group those together so that the access is easier and more closely aligned with the decision processes.

A1: We've been talking in the Air Force about diagnostics systems and what we've really focussed on, at this point, is running hardware on engines. I'd like to submit to you right now that the A-10 system and the EDS system are not diagnostic systems. A diagnostic system is the total of what is being discussed; and the hardware which is out in the field is only that which collects the data, but all the rest makes it a diagnostic system. It's
Go a repository of information which feeds back information, that's the diagnostics. And we don't want to get misled by any contractor or by any person that the A-10 system is a diagnostic system; it's only the input to the system. So we've got to go away from here with the idea that the critical ability is to pass this information around and get it back out for a decision-maker or to aid our decision-making; that's the diagnostic system.

C1: Diagnostics includes the people who make the decisions, a repository of information, the whole works.

M: There are a number of important questions concerning information requirements. How much information can one person really
Df look at and understand? What information should be in the profile, and what candidates are there for subsystem summary? Which should contain the more detailed pieces of information? Which

shouldn't you normally access unless there was a problem or a reason for looking at a particular area? Another aspect is accuracy. How accurate is information and how is that portrayed on the display. Can you at least make some judgement, put some confidence level on your decision? In the format of the data, there is the option of tabular or graphical. There is trending information, recent trends, long-term trends, display as a time plot. In addition to displaying trends, should the system also correlate this information with maintenance history to give a better feel for why these trends existed?

We will discuss the organization of the data base and the access to the information, to identify what functions you have for interrogating the system, how you access the data and obtain certain pieces of information. What sort of interrogation functions should be available in each different level? Also, the concept of management by exception. A lot of people in the Air Force feel very strongly about the concept of management by exception. When does that make sense as a means of displaying the data. Should you only display what the guy needs to know about a particular problem, or at least make it so that he has to specifically ask the system to provide him with certain pieces of information. Age of data is driven by the update interval and the frequency with which the user would be accessing the data. This drives the transfer frequency; how often do you have to update the central data base; what portions of the information need to be transferred immediately; what portions can be delayed?

I'll be discussing two items that were purposely left rather fuzzy within the context of the Phase I study. These were left fuzzy for two reasons: they will be dependent somewhat upon further development activity, and we wanted to allow ourselves enough flexibility. The first area is the specific architecture of the hardware at the base level which will be implemented in the 1980 system. And the second items is this gas path average parameter which we have arbitrarily defined as being undefined. I'll discuss a little bit about how we can do that.

The data management problem within the comprehensive engine management system is significant. Just to do the increments that are associated with parts tracking and spares allocation represents a significant amount of data. To incorporate diagnostics and airborne acquired data into that system is a severe loading factor from a data management point of view. Some of the issues that have to be addressed are the quantity of information, the age of data requirement at each level, because these are strong drivers to the cost and the hardware requirements to implement a distributed processing system.

We've chosen to leave somewhat undefined the hardware at the base. There are two concepts of the hardware at the base which are compatible with what we're talking about today. This first is a smart ground station, or a shop computer, which is used to record engine flight data, automatically acquired, to drive an interactive terminal, and to provide data products. Now in order to implement this with the displays we're talking about, maintenance information has to be input. Therefore, the MMICS computer, the base level computer, would have to be tied in with a two-way direct line. The MMICS computer then provides data products to the central data bank. This is one configuration of the system. It has the attractive advantage from a hardware point of view that the bandwidth or the time to have the data on the screen is much faster than a large base level computer that has to service a multiple number of functions and a large number of people.

The alternate configuration uses a somewhat less sophisticated ground station to record data and to transfer it via direct digital line to the base level computer within which MMICS is implemented. The base level computer then provides the data products to the central data bank, drives interactive terminals distributed around the base, and produces the data products which incorporate both the diagnostic and parts information and so forth.

I wanted to give you a feel for what we're talking about relative to the computer hardware at these locations. As I said, we're flexible, we've specifically left these items undefined because a strict and rigorous definition at this point wasn't necessary.

The second item is the gas path average. This is a diagnostic parameter which is derived from thermodynamic operating data acquired both on the ground and in flight, and processed through a fairly sophisticated computer program which compares this data with what a normal engine sees and what has been reported on that engine in the past. What we have chosen is a module-directed gas path average with a rather loose meaning. It's consistent with the capability of the computer to produce this type of diagnostic parameter. By diagnostic parameter I mean a parameter which gives you an indication of the operating performance, the thermodynamic compression and expansion capability, and indirect measure of things like erosion, foreign
Ga object damage, and the aging of the material components within the module. But, it is referenced and calculated such that a 100% represents the nominal or new performance of that particular component, and 0% represents, on an average, what an extremely degraded component would look like. The critical item here is that there cannot be a threshold associated with this parameter, in the sense that you cannot absolutely say that a gas path average of 49 indicates a failed module, or in the case of an engine, a failed engine, because many different failure and aging modes would produce the same gas path average.

So, to summarize what the gas path average is, it's an indicator. It's a diagnostic in the sense of your body temperature that you can run a fever and not be sick. But if you don't feel well and you have a fever, that's an indication that something is wrong.

B3: I have a problem with this whole scenario from the very start. My problem was getting a handle on the sensors and the reliability of the sensors. Where were these sensors, how would it input in order to come up with these calculations or these trends that you're developing? Now what is this going to do to the guy out on the line with regards to maintaining the sensors that are going to develop this data for us?

M: In the sensor complement for the scenarios, we assume for example, in the F100, it was the EDS sensor complement. In a new weapons system, a new engine, for example, the sensor complement is determined precisely as a trade-off between two factors. One factor is how much additional information can I get about the engine by putting that sensor there? And how much do I have to spend in terms of time in maintenance activity maintaining that sensor complement? So for the scenarios we had, with the EDS for example, there is a given EDS sensor complement.

Se We use that. The algorithm produces a sensor diagnostic which shows that if you have any of your sensor complement fail, it will issue a message saying that, for example, the T2 probe has failed and has to be replaced. This is available in the EDS partially at the flight line. It's available after the processing of the downloaded performance data has been done; and that would then come out in this type of display environment. Now you're right, it has to be a trade-off between the system analysis, how much do you get for putting more equipment on the engine?

B3: Because I looked at our test cell at Kelly AFB, and that thing is pretty elaborately instrumented. But the PML on that — we have a tremendous PML workload just to maintain those components that we put on and off each engine. We don't leave it on the engine. Those are things we have to put on before we, in other words prep for test, that have to be removed after we test it.

M: What you're saying is that there is a question of whether automated engine diagnostics is a feasible concept in the sense that you have to put on sensors and maintain them. Quite frankly, the answer to that question is not hard and fast. There are no automated engine diagnostic systems in the field. Now the IECMS is being flight tested, and very detailed measurements are being made relative to the maintenance required to maintain the IECMS
Te TF41 engines with the automated system and without the automated system. The same type of testing is going on at Myrtle Beach for the A10 TEMS. This study is predicated on the utilization of automatic data acquisition of engine data. It doesn't deal with justifying whether you should have one or should not have one.

A1: One significant thing I'd like to point out. Many of these systems which exist today depend upon highly accurate PML or maintained instrumentation. More recently, we've found out that the sensors, even though they're not precision sensors, the data that's coming off them is very repeatable.

C1: So the trend is more significant than the actual reading.

A1: Exactly. Our program here is set up to handle the trend rather than the precision thermodynamic calculation.

4.2 Base Status Summary (Figure 1)

M: The first display that you'll be seeing is a base status summary. We're indicating on the screen the number of aircraft, of the 40 aircraft, which aircraft are fully mission capable, partially mission capable, not mission capable, either because of supply or maintenance. And in the two aircraft that are not mission capable, there's an indication of a hole, because there are not two engines installed. For the engines, we're

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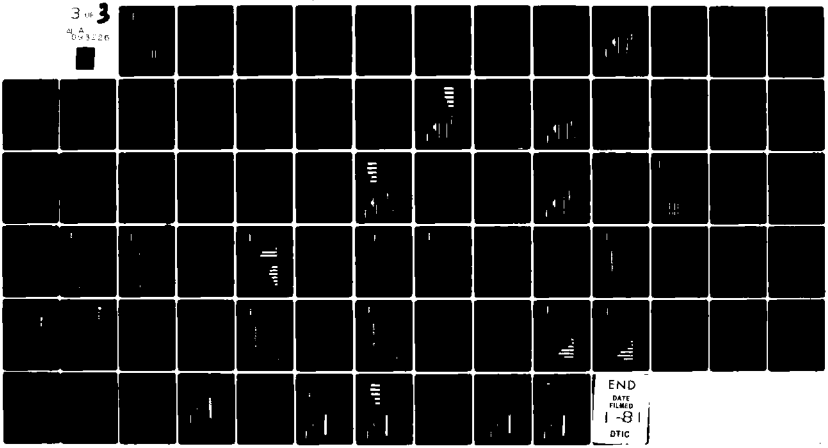

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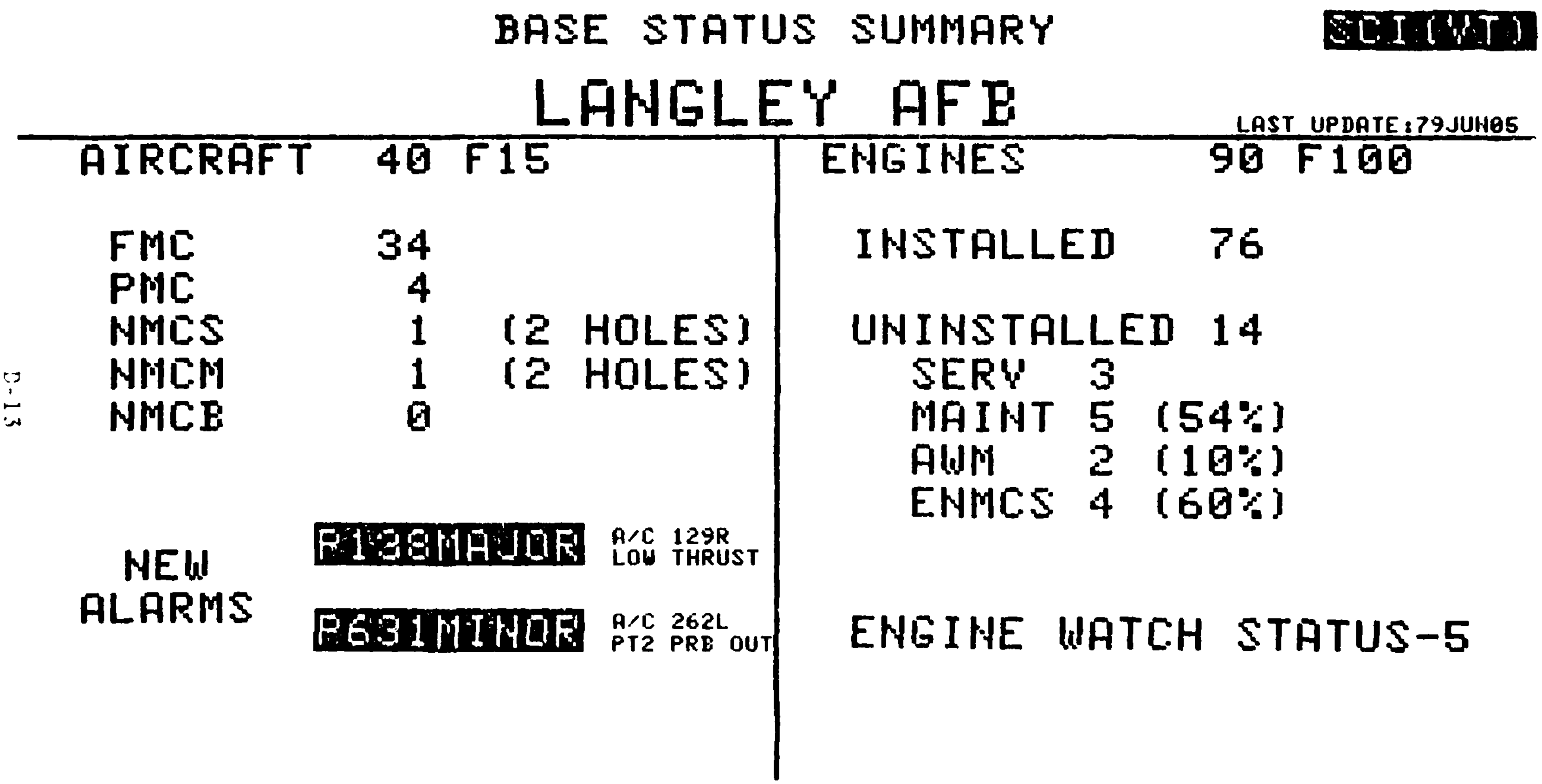

Figure 1 Base Status Summary

at 76 installed engines, and of the 14 that are uninstalled, 3 are serviceable, 5 are in maintenance, 2 are awaiting maintenance, and 4 are not mission capable because of supply problems. The percentage at the right indicates an average; of the
BS 5 engines that are in maintenance, approximately 54% of the work is complete. If you were to look at a summary of the uninstalled engines, it would tell you specifically which are the uninstalled engines and at what point they are in the maintenance process. There was a major alarm on engine serial number P138, indicating low thrust. That engine is installed in aircraft 129. A minor alarm is indicated on engine 631. There are 5 engines currently on watch status.

A1: I have one question. Are there additional pages if the alarms and the watches exceed the space?

M: There would be. In terms of the engine watch status, the only indication is the number of engines on watch status. There would be another report that would give you an indication of why it is on watch status and some other summary statistics. You'll notice we use the category new alarms; those are the alarms that have occurred since the last update of the data base. If the age of data were, say 24 hours, and the data base was updated every night, based on data from the day before, we would not have much more than 4 or 5 alarms. A choice might be made to indicate the number of alarms and call a display that would explain each one to some extent.

D1: Question. On the waiting maintenance and ENMCS there, that percent figure you've got, what does that mean? Are we talking about maintenance manhours that are remaining to get that to 100%, or what hours, what maintenance manhours are we talking about?

M: For management, what would be the best way to express that? You could talk about a job that's 80% done, or requiring 10 more
Ms manhours.

D1: To me, that would be more significant, the number of manhours.

B1: Manhour backlog would probably be more significant relative to maintenance, and relative to ENMCS, I would assume that possibly a calendar period would be more specific.

M: Like estimated time to completion?

B1: No, estimated deliveries, more than anything else.

D2: But where would that information come from?

B1: Well, it would be accessed out of the supply computer. If you're addressing engine management in this sytem, you're going to have to have the ability at the base level to tie into
Ba all existing programs.

M: Is that a MMICS capability or is that a different processor? Is it resident in the Burroughs computer at the base level?

B1: No, it's in the 1050 computer.

C1: The MMICS and the supply computer are two separate computers.

B1: But, right now, don't we get a MMICS playover to the supply system? Isn't there a MMICS program that gives you your due-outs and supply status?

C1: That's on the supply computer, and that's Reel-24, D18.

B1: Yes, D18, I know is the supply computer, but I thought there was a MMICS product that we could get out of the system that was a tie to this, whether it was put in by material control
Br in the statusing of those aircraft, I don't know.

L2: That information might be there or it might be available with input from the system here.

M: How important are those two figures, awaiting maintenance and the ENCMS percentages in a summary display like that.

B1: The fact that we have AWM should probably be displayed in the probable manhour backlog that those two engine- would incur. In other words, the engines were removed for some cause, whether it's a scheduled cause or an unscheduled cause; it was removed for that cause. There's a specific path of
Ms maintenance that one would run through to solve that problem and return that engine to serviceable, which has a standard, a job standard, attached to it, from which one could imply a standard maintenance backlog to those particular engines. There wouldn't necessarily be a standard maintenance backlog for each engine, there would be a backlog relative to the cause.

L2: Where's that information now?

B1: There are job standards for specific types of maintenance within the maintenance control complex.

C1: That percentage number is a number that the branch chief normally uses on a day-to-day basis to give him his overall status. But it applies more to specific engines. It doesn't have a lot of meaning when you group them.

M: Okay. So you think manhours on an overall daily display like this would make more sense. And then if you specifically looked at a display (as we will later) of uninstalled engines, then gave it a percentage completed, that would make more sense at that level?

B1: It would be a management tool that would be applied to programming the next day's effort or the following week's effort, or whatever like that.

M: How about eliminating 60% figure altogether on the ENMCS?

B1: The percent ENMCS doesn't mean anything to me.

C1: What he's saying is that on an average, those four engines are 60% complete, ENORS. I think what you really want to know

for the ENMCS is the number of items you require, and their estimated delivery date. Here, you're looking for "Am I in
Ms trouble for supply delivery dates," on a gross look?

B1: There should probably be an overall manhour backlog in work or removed backlog. In other words, these are uninstalled engines; three of them are serviceable, the backlog assumed for those uninstalled engines is the following. And then, specifically, four of them are out for supply, which attaches a different principle that is a calendar basis. So you'd have to estimate when the status would change on a calendar basis. Since there are four different engines, I don't know what you would do.

C1: Let me suggest something. From a management standpoint, particularly if the spare line happens to be low, it would seem to me that the two AWM engines, for example, may be relatively minor jobs, but there is a manhour figure sitting off to the side for those that may dictate that you work those before something else.

B1: Sure. I agree.

C1: And it would seem to me that you would want to know the manhours for each of those categories.

B1: Right.

M: Okay. The suggestion then is to replace the top two percentages with estimated manhours to complete, and remove the 60% and access that information on a per engine basis.

B1: The other thing which doesn't seem to be there is the following. There are aircraft that are down for not-engine reasons, which indicates that there are that number of spare engines available.

M: There's an indication on the aircraft that are down for supply and maintenance, that you've taken those four engines and placed them somewhere else.

A1 C1: On the malfunction indications, how much confidence do you have in those? Frequently, the way we do business today, using the reports we have, an engine will come into shop for a suspected problem, and in the course of maintenance it turns out to be a completely different problem. But that initial problem remains in the data bank. Is this derived from that same kind of exercise?

Dm

M: This is a new alarm, and it has come in only in the last update of the data base. This diagnostic is relatively certain; in other words, you have a high probability of being correct. This flags things that are really bad. Things that are degraded may be in the gray region and appear as performance types of information.

C1: Okay, it will be less specific.

M: Less specific. And those will be the things that show up on a watch status. We'll see a couple of examples.

C1: Again, that's really key for planning, because if the guy doesn't have confidence in what that's telling him, he's not going to use it or if he does us it, it's going to detract from his overall performance because he's going to be wrong.

B1: What would be the impact of an alarm in there? Should there be an indication whether those few particular aircraft are scheduled for an event within the next so many hours? From a management standpoint I need to know the status. It should flag that during the interim period those two problems were found on those two engines, and they are on the schedule for the morning's flight. Then I need to decide whether immediately I must get someone working on them or not.

M: Right now, how is that flying schedule information available?

B1: It's formulated on a monthly basis, formulated on a weekly basis, entered on a daily basis, and revised on a daily basis.

M: How accurate is the monthly basis?

B1: Not very. It's a general guess because it takes into
Fs consideration, all scheduled events that may happen to the aircraft during that month's period coming up. So it drags them off the schedule at various times to allow those scheduled things to happen. It takes into consideration the unscheduled things. The weekly schedule defines it a little bit better. And then of course the daily schedule represents what is actually happening.

M: Is this the type of data that would be easily available on a written report, or should that be accessible within the information system?

C1: The difficulty is that it's not in the computer today at all locations. ATC, for example, uses the computer to schedule. TAC and some of the other commands do it manually via written report, and it's updated daily. But the point is well taken. When he sees an alarm, he's going to go to the flying schedule, whether it comes out of the computer or whether it's on a report, to see when he has to work that problem.

M: But again, it is the question whether you think that information should appear there, or manually on something that he would normally have in his office.

B1: This piece of computer information will do away with a manual procedure which currently takes us a long time to perform.

M: Would you say that's a viable candidate?

C1: Yes, you may not be able to incorporate that immediately, but it's certainly something to look at.

4.3 Engine Profile (Figure 2)

M: The next display is the profile of the engine with the alarm. We talked earlier this morning about the information chosen as candidates to appear on the profile.

B2: "LAST TRIM - OK" - What's the significance of this?

M: The performance data is used back through the T/O spec to predict whether you're within the EPR band.

B2: You lost me. All the airplanes flying, trim okay, unless the pilot has a squawk. So this one comes up with low thrust, yet the TRIM says OK. I don't get the significance.

M: You've spotted an inconsistency in the display. TRIM OK indicates that all of the trim parameters are within bounds based upon the last updated. This particular case shows low thrust, so TRIM would not be OK. That's a mistake.

B2: Okay, I can understand that, but if one of the parameters is out...

M: You'd get a diagnostic.

B1: I don't really see any need for that display, period.

M: Why not?

B1: It doesn't tell me anything. It tells me the same things that I knew when I got the alarm, that I've got low thrust on that engine.

Ep

M: It is intended to be a summary index to access the per engine S/N data.

B1: The only thing that's significant there, as I see it, is a core engine GPA jump of -33%.

M: That flags the next display. Now you go in and say "How much is that?" and it comes up and shows you specifically.

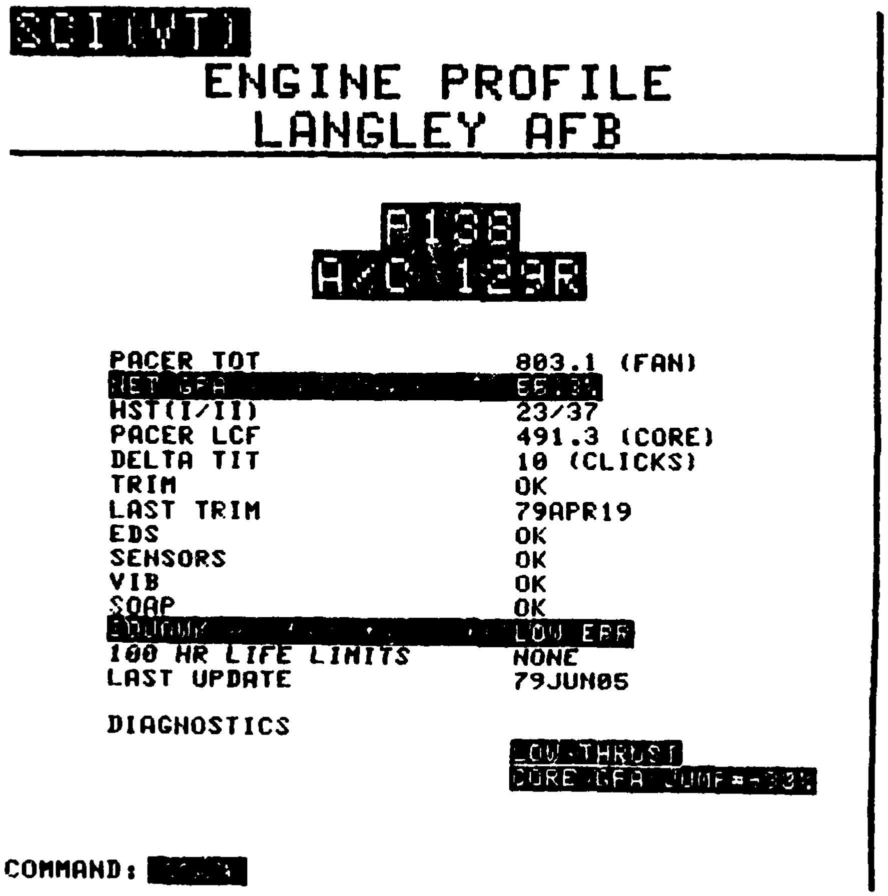

Figure 2 Engine Profile Flagged By Alarm Message

Ep B1: Okay. I've got some historical data that I'm not sure I need because I haven't made my decision on what I'm going to do. I might need the historical data if my decision is to pull the engine out now and work on it.

M: What information would you want?

B1: Well, I know that the fan is the pacing module. I've got an HST, 1 and 2, but not as percent of TOT, so I don't know that I've crowded HST on all of a sudden in the last little bit. It doesn't give me anything there. I've got an alarm. I've punched a button that's supposed to tell me what I've got to do next. All this display tells me is that I've
Da got to punch the computer again. I'm still at the same point I was when I read the alarm. I know that the engine's got low thrust and I've got a problem.

Now if the pilot squawks, and he had EDS on board, I assume he would punch out the EDS to get a picture. Something told him he had low EPR. He feels in the seat of his pants that he doesn't have thrust; so his write-up is low EPR, and at that point in time he should have punched the EDS to say "take me a reading now, because something I feel is wrong and I don't know what." So that reading should already have dumped into your machine here and specifically, the machine should have answered the maintenance people saying, "Hey, here is the reading, here's what's wrong."

M: That's the problem. There are many causes of low thrust. You don't have sufficient information to say "I have low thrust, and specifically the problem is as follows..." We're not trying to replace the maintenance person diagnosing the problem in the
Dm engine.

B1: Principally, this is a history-type of a system. So in effect, what I've got here is... supposedly, this is not Day 1

and this is not the first entry that's come out of the system. I've got some history back of me there; I've got a low thrust, low EPR write-up, which indicates low thrust and I've got a -33% core GPA and an overall drag on the total engine, which I don't know what percent that core is of the drag. In past cases, when I've seen this type of a parameter display through EDS, the corrective maintenance action had been change an FTIT probe. So specifically, what I need to see there, more than a lot of historical data that doesn't tell me how to get to the basis of the problem, is I need to see some probabilities thrown up there on what my next maintenance step should be; and then you turn the maintenance guy loose to do his diagnostic, following the best possible procedure routine that the computer
Da says gets me fixed and back in the air fastest. Sometime during the troubleshooting, he may stumble across something which turns this thing around. Now we need a way for the maintenance guy to access the computer to say, "Hey, your logic wasn't quite correct, because in this instance, doing this procedure, I found this." And that goes back into the history again; and you've created a new file under low thrust. Or else, your system, as a maintenance management system, is only going to be a typewriter, and it's only going to say, "Hey, here's some useless information," and it doesn't drive the situation at all.

M: The idea of the computer diagnosing the problems or supplying among a basically infinite set of possible causes of particular problems, a group of probable factors is a problem. What we are seeing here is the way that an immense amount of historical data is indexed. The reason for the indexing is that, for example, the screen that you see is of finite extent, that is the amount of information that can be put on there is limited. This drives a hierarchy of information.

B1: What I'm trying to get to is to cut down on the amount of stuff that is on the screen and just put out the significant points for problem solution ... drive the problem solution.

M: We had a version of that in the survey, which was a display like this with almost no information on it and basically the information that was displayed was only the exception information. In other words, you have a listing of the things in the data that were abnormal. Use those to drive the next things you will be seeing. The overwhelming response on the survey, however, indicated that...

Me B1: My response was the same on that thing. I wanted to know everything.

C1: I think that for the purpose of formatting the data, you are pretty much constrained to going in this manner.

M: That's the other point I was going to touch upon; that it simplifes the data system. If we choose a given format of display, it will solve or be useful in acquiring data for a
Df wide variety of problems, in this case, on a per engine basis. What we are trying to get at is a single display that we can have as a standard item -- a standard data product.

C1: Within the operational environment, I think what he is saying is that he's not going to spend any time on this chart. He may have to flip it and he's going to go directly to the next one. If, however, instead of a "LOW THRUST" it simply says "PERFORMANCE" down there, he may spend a bit longer looking for some other clues.

B1: It doesn't key me to my next action. See, just because I have a LCF counts on a core does not mean that the core may be close to a scheduled event.

M: Would you rather see, for example, remaining LCF to an event on a pacer module basis?

D2: Either that, or get back to the GPA correlation with time and cycles.

B1: I don't have an event on there that really tells me what percent of the net GPA the core has affected. This is my main point - the first thing I flip up on the board that makes the decision on what to do. Am I going to call the guys out there to troubleshoot the thing, or can I make the decision, "hey, this one is so close on scheduled events and on all other param-
Ga eters to go into hard maintenance, that I might as well pull it down and get it into hard maintenance and not waste AGS effort."

M: How about adding an additional column? Another column would be a directing action, for example, to access to the GPA trend. Under the PACER LCF or TOT, it says, "look at the history of the time/cycles."

B1: There ought to be a lineup -- "not a candidate for immediate," or "candidate for immediate removal based on schedules" and then you go in and you pump your schedules button. If it throws up what you've got there, you automatically see there is a fan coming up on schedule, a gear box coming up on schedule, and this core is rotten for some undetermined reason. That's three modules. That gives me the authority right then and there to take a transfer action of that engine down to the depot.

Da M: How about displaying an item that directs you to push a button.

B1: That's what I mean. You don't have anything to drive me to the next input. Now, if that input happens to be 3 letters and a number that I have to punch, then that input out to be displayed - 3 letters and a number - so that the guy can just punch it in. He doesn't have to look through a chart to figure out what three numbers he needs to punch next.

M: That's a very good comment.

B1: The maintenance status that I'm looking for is "What's going on today?" I don't want to have to make the decision, the decision should already be made and here is what I am doing today.

M: The real requirement that it lays on the system, is that during the debriefing or prior to debriefing the aircraft being squawked is down-loaded.

B1: If it has an EDS on board. Let's just not assume that. I hate to assume that we are going to have EDS or some on-board unit on the weapon system.

Te M: In that case, the diagnosis of the fault has to be made upon data prior to the flight and pilot's squawk. There is no reason that could not be done. That is one of the things we're trying to establish. Maybe one of the requirements we have is that located in the vicinity of the debriefing area, is one of the terminals.

B1: I think your approach at each level within the base is to determine what has to be done and tell me what has been done already.

D1: I think we have already made the assumption that the EDS is on-board because it's right there.

B1: Instead of EDS you could just as easily have EMS there.

M: The information explained here is for an F100 EDS system, but we're not constraining it to anything like that. What we are interested in is the items of information that should be there and if there is an automated turbine engine monitoring system on this engine, then there would be an item there corresponding to that, if there was not, it would not be on there.

D1: I don't see the significance of a squawk at all. There
is no reason for a squawk because if he has the EDS, he has
an indication that he's got low thrust, EPR is low. He punches
the button, it takes all the recording right there at that point
Dm and time and when you dump it, down-load it, it's right there.
That's where you really need to start pulling apart. Not the
fact that it is low, but how low is it?

C1: Keep in mind that this data is going to be used in a number
of different areas in maintenance complex and you and your
specific job may not use everything on that sheet, but I may
need it a day later.

B1: Absolutely, but I think what we ought to try to do from a
field standpoint is to address problems with our weapon system.
We're addressing a computer system to help us manage what we
do on an airplane. So, you have to really start your thinking
at the level where the problem occurs first and then figure out
all the management aspects, e.g. when does this guy have to see
this daily status of engines and what should be on it relative
to when the event/problem occurred. What's the logical sequence
of maintenance events after an event occurs? Well, it's going
Go to be debriefed. Then some decision will have to be made as
to whether it gets work now or gets work later. Then, when it
gets work, how do we work it? What's the best route to follow?
What's our most economical route to follow? Is that engine so
close on time that the most economical route is to pull it.
Those things would have already occurred before this maintenance
control officer comes in and punches D for Daily Status.

C1: In order to make those later decisions, you've got to know
what the problem is now. Because, even though you may be within
Ms 10% of the core limits, if you don't have a spare engine, you're
going to fix this one to fly on that 10%. What I'm talking
about is the decision process that gets you there. I think that

the decision process has got to be the same for each problem. Recognize what occurred, what the cause is, then what you're going to do about it based on all of the data.

B1: Now let's take the problem as it occurs. It happened, the pilot reported it, it goes into debriefing. There is the first place we need some information.

C1: We want to know what's the cause of that problem. Then we can make our decision as to what to do about it.

B1: Here's the best probable route to take based upon this engine's history and the current problem with the engine. So it gives you a couple of routes to follow. Here is the point where now we need to make a management decision and it has to come up to a statusing level.

C1: I still don't understand that.

B1: The guys down in debriefing don't see the big picture of
Md the wing. They're not the guys who make the decision. They are the ones that input these little points of information. They troubleshot this system. *The computer told them the best* possibilities based upon this engine and this problem at this point in time. All of those things should be forwarded to the management level.

M: Let me restate this. We go through the scenario of a squawk during debriefing of low thrust. There might be a terminal in the area. An entry might be made right at the time of a pilot's squawk. From that point on, it is available to anyone else. Further displays are accessed in the debriefing room to indicate what might be wrong. If it's a more subtle problem, there might be other management decisions that have to be made, it might be deferred. In another level, higher up for example, in scheduling maintenance at some later time, maybe an hour later or half a day later someone gets this type of display again, and he can go in and look at all the age and cycles indexed by this piece of information and then he can prescribe his maintenance. We are trying to get from you guys what we put up here. What pieces of information. We will come up with one display updated on a periodic basis from downloaded EDS data or from a pilot's squawk in the debriefing process, manually.

B1: The displays should be generated for the level that the display will be used. And they also sequence themselves in time of requirement and that sequencing of events should drive you to the logical display.

B2: The last update was 5 June and that thing was output 6 June. Is there any way you can indicate what system was worked or whether it was an 04 (TRIM) or a 2300 (TURBINE ENGINE) work code prefix. Is there any way to indicate that the last update was something about changing a fuel pump or a fuel control or whether they were changing a clamp on the oil cooler, since the latter has no relation to low thrust.

M: "LAST UPDATE" refers to EDS. The maintenance history can be accessed with another display.

Da B2: Is there any way to show evidence of acknowledgement. If we get the low thrust and some guy decides to fly the airplane, can we get a signature or man number or some indication that someone saw this?

B1: He's got a good point there because the pilot may have written up low thrust. That thing up there says, "Hey, there's nothing wrong with the engine, go look at the airplane."

M: The display indicates low thrust was squawked and, in addition, the performance measurements corroborated it.

B1: But, a 33% may be within the acceptable band of that particular engine and there ought to be something on there that says "this is acceptable."

Dm D1: But that would not be an instantaneous jump.

B2: Is there some way to show if this is a flyable condition.
The pilot could fly with low thrust all day. Should we drop
Dm one 750 lbs and let him go? What I'm saying is, ideally we
have a known fact that if your engine is, say, 2.1, then you can
fly with 800 lbs of bomb. If it's 2.0, you can fly with 600
lbs of bombs. When you're looking at it, it's usually a TAB B
situation. These guys are coming back with a 1-hour turnaround.
If this thing's going to work, it has to make money for us in
combat, not peace time.

M: A display that shows no diagnostics would indicate a flyable aircraft even though some of these events occurred. This system is resident away from the flight line. As part of the EDS system there is a flight line diagnostic unit.

B1: I got the distinct feeling that you are hung up on EDS. The program ought to have a little bit of looseness. Don't get hung up like that.

Now there is an alarm on the status. The guy's next logical thing was to punch this display.

M: That's right. The set of possible failures that can occur
can be picked up at the flight line is smaller than the set
of all possible things that can go wrong with the engine. The
pilot in debriefings squawked low thrust and in addition, more
detailed off-line processing indicated that events occurred.
Te In addition, historical events are brought up because that's
going to affect what's going to go on next with the disposi-
tion of the aircraft.

B2: Do I have to detect a relationship to MADARS? If I do, then you know that MADARS is really a neat little trick. It does a lot of things for both maintenance and AFLC. Why don't we just take MADARS and improve it?

M: This might be looked at, in fact, CEMS might be looked at as the next generation of a MADARS concept.

This is a fresh look at the problem. We're doing a systems analysis study of the user requirements not specifically tailoring a system of software.

4.4 Gas Path Snapshot (Figure 3)

M: The next display is a GPA snapshot. It portrays the relative health of each of the five gas path modules, and their serial number.

D1: You lose the cycles on the HPT.

M: Would you prefer to have that rather than total operating time?

D1: On those two, you work with the cycles.

Ga D2: What they're putting up there is a gas path analysis. They're hanging their hat on this GPA number telling us more than time and cycles. There may be a correlation, at this point unknown and unspecified, but what we are looking at is a GPA number which goes from 0 to 100, a 100 being fine and 0 some severe degradation in performance.

B1: I still don't feel this gets me to a decision. I see a core indicated there and I see a HPT and I know that I've had a 33% jump in the core.

D2: You had a core performance degradation of 33% from the last time this EDS information was updated.

Md B1: From what I'm looking at right now, I'd say I just FOD'd a core.

M: That's the right decision.

B1: I don't see that there. I know what you're trying to say, but I don't see that there because I didn't see what was there
Tr before. If I look at the HPT, that's floating along; it may have been floating along level, but I don't know that.

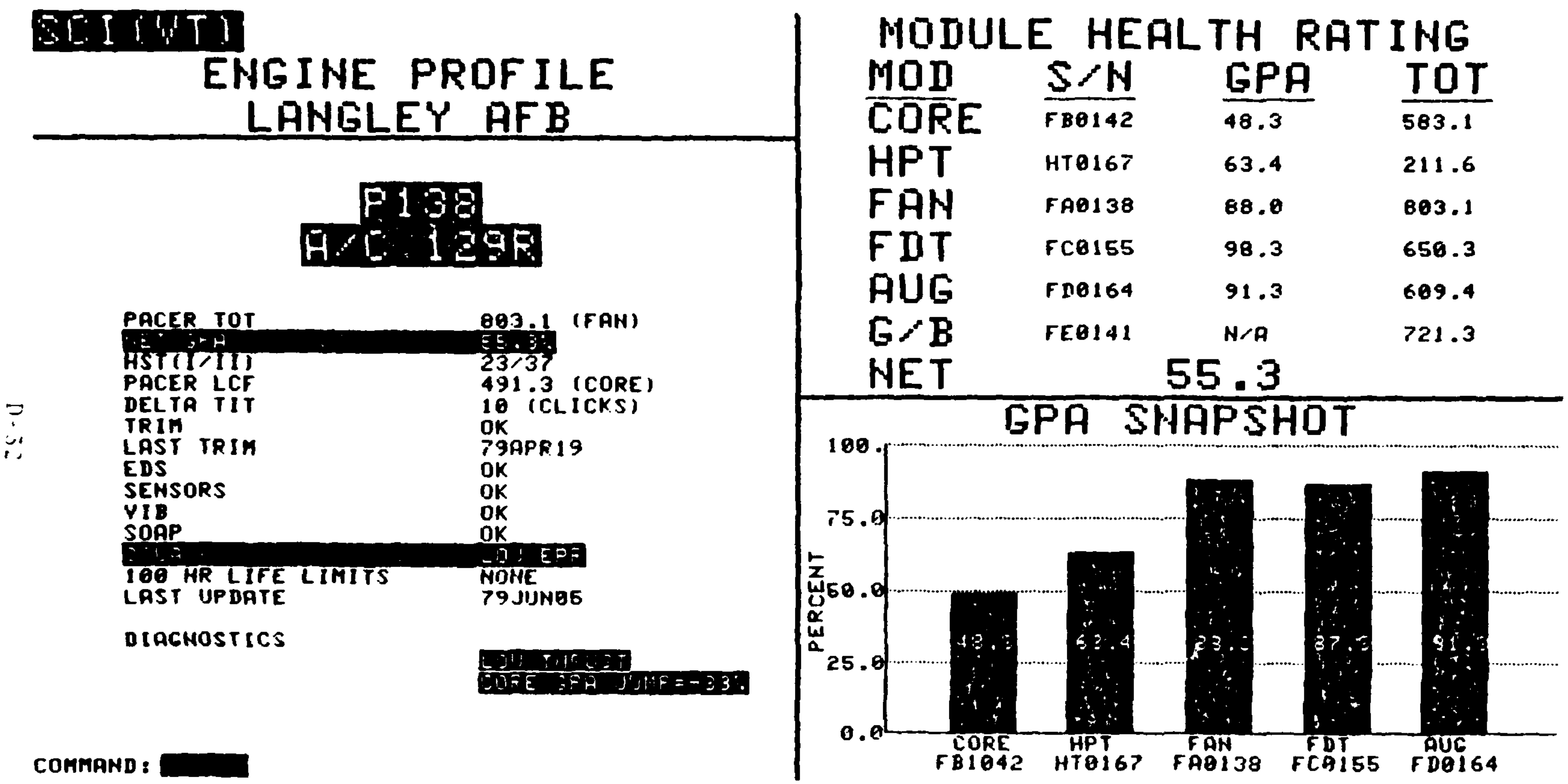

Figure 3 Tabular and Bargraph GPA Snapshot

D2: One of the other things is that with a system like this, counting time and cycles, if you're mixing and matching modules, your engine has to be instrumented to count not only overall engine cycles but module usage.

M: You see the advantage in having a base level historical data base. You just have to count engine cycles and accumulate them.

D2: But the software has to add those cycles into each module.

M: The base processor linked to the data base has module serial numbers and catalogs all the modules which are then up-
Tk dated.

B1: Are we saying here that I either have the bottom GPA snapshot, or I have the top module health rating:

M: Yes.

B1: I wouldn't get both of those on a snapshot?

M: You could get both.

Tr B1: If I wanted to trend rather than to look at a GPA snapshot in the bargraph form ...

M: That's coming up next slide.

B1: At this point in my access to the computer, I don't want to see that, because I don't need all of it. I'll need it later on though.

M: At some point, you might want to look at that.

B1: I've hit the computer three times now and I still don't have my problem answered.

4.5 Gas Path Trend (Figure 4)

M: The gas path trend correlated with maintenance history is shown on the next display.

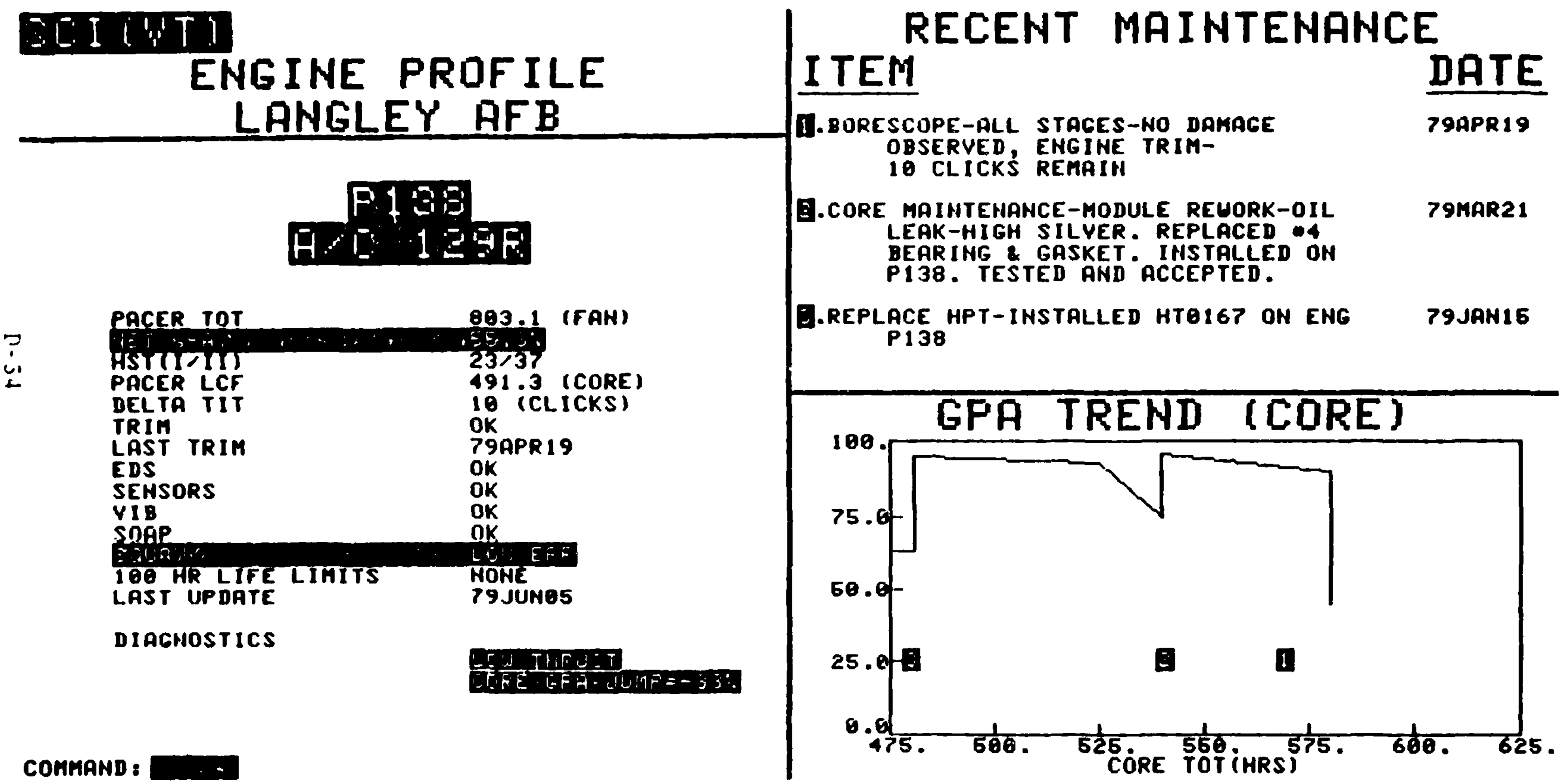

Figure 4 GPA Trend Correlated with Maintenance History

D2: The computer sees all of this information that the core is the lowest and it should automatically just spit that out for you instead of you having to go through one or two iterations.

B1: Back in the first display, I already had it figured out that it was FOD'd. I was taking it for granted because none of the other modules were displayed and there wasn't some other information to drive me to another module. The most probable
Tr thing that I had was a FOD'd core.

M: Then you would not have needed access to this display.

B1: You have to take a look at who's going to be looking at this information. Can anybody, at any level, come up with the right answer?

M: You indicated that you can do it from this one.

B1: By feeling that if there were something else in there that should be presented, the thing would have presented it.

D2: You would see it in the GPA.

M: The problem with having the computer make a decision is that there is a finite probability that it will be the wrong
Da decision. In other words, we're not trying to replace the human in the loop.

B1: I understand that, but this is an access thing. Its availability of data to make a decision.

B2: Does it only display the core because it's less than 50%?

M: The last 100 operating hours may be the critical interval and you might specify the core specifically. Look at the information content as far as boot-strapping these displays to appear
Df automatically or to appear on user request. Let's concentrate on the items of the display and see if we can change those and worry about the boot-strapping operation later.

Ga B1: Again, GPA takes in what parameters?

M: The gas path analysis is done with the performance data that is acquired with the TEMS.

C1: It will vary from engine to engine.

M: Depending also on how the modules are configured. The module-directed parameters are dependent upon the modules. What we specified here is a 100-hour limit. We thought that would be a reasonable interval on which the trend automatically. You could ask for the last 200 hours as well. Would it make sense that the last 100 operating hours on that core would be

Ad what you would be interested in looking at?

B1: The thing that I see is that the maintenance actions indicated are relative to changes in the trend.

B3: You say you are not going to lose any of those maintenance actions?

M: No.

B3: How often should the trend of information be updated? What are you talking about here? You should update every time you do an action anyway.

M: That's correct. The question is, does it make sense to do it that way or can it be done less often?

B3: My question is, how long does it take to update it?

M: The information is fed in about once a day. The trending procedures are something that require computer work, especially if you have a large number of engines and it might take 15

Ad minutes of computer time that could be scheduled in easily at 2 o'clock in the morning if it's an automatic process. But on the other hand, if you only did once a week it would require less computer resources than if you did it once a day.

D1: The onboard electronic processing unit has to be dumped periodically into the DDU. That unit can only hold so many engines worth of data before it has to be dumped into a permanent storage.

Tr D2: The trend data gets put on a disk where we can print it out. In fact, the trending was an item at the last diagnostic meetings which got quite a bit of attention. One of the items which came up there was that a feasible means of handling the trend data would be via some type of compression technique. You would only take a look at the individual points from the last so many hours, whatever that may turn out to be. You could actually look at the points for each individual flight and all the data prior to that, you see as an average trend for those hours. You see this average trend and then look at your individual flight points. One of the things that I brought up at that meeting and I'd still like to see is the possibility for
Da the operator to look at a particular window or to sort, i.e. to take a look a little more closely.

M: In other words, go through all the data and pull out all the take-off points or whatever by window?

D2: Yes, that type of flexibility.

M: That flexibility should be in this type of system. Would you suggest that the people in the maintenance area who are doing daily type work would use that?

D2: People in the shop may want to do that.

B1: There's another thing on this that you really need and it goes along with what you were saying here. When you have a malfunction, it could correlate with the type of mission flown.
Co You ought to keep that data in the history so that you can see if there was a trend in "type malfunctions" relative to missions flown.

M: Do you mean held within the history over the last 100 operating hours?

B1: No. For example, for this low thrust write-up. If he was in a specific mission environment, in a specific spot in the envelope, the low thrust that both the sensors and diagnostic system are reporting and his seat-of-the-pants feeling may be perfectly normal operation.

D2: What you're asking for here is, what happened during that particular flight that this pilot squawked.

B1: The fact that I'm trying to make is when I got that 33% drop, 33% GPA, that is one reading that I formed. Now, if I'm in a mission that has by its environment dropped the engine to that point, that's a false point that I'm looking at.

M: The flight point that produced that diagnostic was a stabilized condition.

B1: The way I understand EDS, if any parameter goes out of an exceptable range, it will ring up the system and snapshot.

Dm C1: That's an event as opposed to a trend, or a performance snapshot.

M: But that data is not used to make this calculation. The only data used is the stabilized performance data.

B1: So, possibly there should be an entry in the first display that would indicate that this is a stabilized data point.

4.6 Watch Status (Figure 5)

M: We discussed the concept of a watch status. Here is a watch status report where five engines have been flagged. It lists their location, the reason for the flag, current GPA rating, clicks remaining, the pacer module, hot section time and life limits occurring during the next 100 operating hours. The reasons used to flag an engine on a watch status include a deteriorating trend of GPA, vibration jumps, SOAP trends, life limits. On the second engine, the core is due for 900 cycle

Ws maintenance within 15 operating hours. A large jump in the gear box vibs on the third engine suggests monitoring SOAP. The fourth engine shows change in the SOAP, i.e. nickle for that particular engine over the last 20 operating hours. The fourth has low performance and a trended GPA dropping.

D2: This is the normal data that you are feeding in to the system and it automatically prescreens it? Is this a separate data input that gets put in some place or is it using the current information to give us this engine watch status?

Da M: If you flag an engine for being on watch status based upon the fact that it had a lower performance ...

D2: So an operator would have to say, "I think we have an engine here that we're going to watch," and then he has to do something, and the system will track it?

M: Very much like a SOAP too, which says if the metal is high, monitor pre- and post-flight and watch it. Should you automatically insert it into watch status?

D2: A person reviewing data items would have to go to his terminal and input a serial number and indicate this or that reason?

M: We're talking about automatically putting an engine on watch status. The computer would make the decision.

SCI(VT)

ENGINE WATCH STATUS

LANGLEY AFB

LAST UPDATE:79JUN05

S/N	LOC	REASON	GPA	ΔTIT	PACING MODULE	HST I/II	LIFE LIMITS
P168	188R	LOW PERFORMANCE-GPA TREND=-0.5%/OP HR	59.2	10	HPT 91.8 HRS	168/182	1ST STG TURB PLT-82HRS
P206	141R	900 CYCLE CORE-DUE 79JUN22	79.9	11	CORE 889 CYCLES	42/25	CORE 15 HRS
P342	155R	1.9MIL JUMP IN G/B VIBS-MONITOR SOAP	81.3	12	FDT 780 HRS	33/21	
P403	143L	N1-1.2PPM/HR JUMP LAST 20 OP HRS	84.3	8	G/B 832 HRS	39/18	
P555	111R	LOW PERFORMANCE-GPA TREND=-0.4%/OP HR	60.2	7	HPT 803 HRS	66/32	

Figure 5 Engine Watch Status Report

D2: This is an engine watch status as a result of limit exceedances and GPA degradation rates and it's done automatically or it's not done automatically?

M: The information is updated automatically. It could be flagged automatically, manually or both.

C1: I think it really ought to be done automatically. I would prefer to see it separated. Those that are running out of life on some parts on one page and the performance problems on another. My life-limited parts I may only look at once a week. Performance-oriented problems I may want to look at daily.

B1: What you're assuming is that a life limit drove the watch status. I would not assume that this is what we're doing. The watch status could be driven by a trend of 0.5% per operating hour of low performance. And when you look at the HS1 and HS2 you would see that you have bad FTIT problems. If there is a life limit in a very short amount of time, can you go in with an inspection or a check on the probes and still
Md keep the engine running or should you go in there right now because those probes are beginning to show the wrong reading and you are burning up the turbine right now.

M: The watch status is meant to be the categories which don't have a maintenance action required immediately, inspection or anything like that, but which maintenance may be imminent.

D1: You're talking about cycles over there in the pacing item and yet when you're talking about life limit, your talking about hours. What do you do when you have x number of cycles left?

B1: This is one thing you need to clarify. If the intent is
Lu to display life limits as time remining in engine flight hours then it should be so stated.

Just take the top one up there. Say specifically that the engine had the cover plate replaced at 100 cycles, so you still have some cycles remaining, and that equates to 82 flight hours.

That's really what you're trying to say there, but its confusing.

D1: You can fly the aircraft from Holloman to Spain and in flight refuel it five times and only create one cycle.

M: Yes, we are using the engine flight hours to cycle equivalence standard for that engine that's determined for the fleet by AFLC, for example, the F15 is 1.37 or something like that.

B1: I would not like to see that. This is a base level item. Your computer should provide the average cycle equivalence
Lu for that particular base. They are all different and the 1.15, which is the number you are searching for, is so erroneous it's not funny.

M: You would like to see a utilization rate which is base-specific.

B1: If you're trying to tell me, "I've got this much useful life remaining," then it should be the useful life at that
Ws base. Also, the watch status engines should reflect the aircraft deployability.

M: Do you think that the definitions of watch status is that you wouldn't deploy with that aircraft?

B1: Well, for instance, if I have 82 hours remaining that would probably pull me underneath transfer limits. But a person normally reviewing watch status may not really equate that. I'm asking for a little more information, like an asterisk. That would indicate nondeployable.

M: Do you think that the watch status concept is a good idea?

Da All: Yes. (Consensus)

B2: If you start creating these data products which forecast the ability of wings to sustain war, like how many airplanes can we send, would that be classified output?

C1: No, because these are only recommendations as to what you would want to do with respect to deployment situation. If you are out of airplanes and you need an engine, it doesn't make any difference what's on the display, you're going to deploy it.

M: Parts of the data system are confidential and will be secured as such.

B2: They will not be accessable then?

M: That's correct. There is a whole series of security-type requirements. If you do see anything in any of these that would be a confidential item or that would require security protection, let's flag it.

4.7 Engine Profile - Trending (Figure 6)

M: This is the engine with the performance trend dropping about .5 percent every operating hour. You can look at the trend for the last 100 operating hours at various intervals.

B1: This is more consistent with what we would like to see, i.e. the effect of the problem against the overall trend.

M: Would you say you need both the snapshot and the trend?

B1: This display gives you an idea of the maintenance category the engine might fit into, relative to scheduling.

C1: Really the GPA snapshot indicates to you which modules you want to test.

B1: It's helpful to have both of them up there; to look at your overall engine and the module, and then trend what you want.

C1: Can we see the HPT and the core against each other?

M: Yes, that's possible.

D3: How is the net GPA different from the individual terms?

Ga

M: It's a weighted average.

D3: The weight pulls mostly on the core and the high pressure turbine?

M: Yes.

B1: We want to provide some information for the guy to make a
Df decision on what he's going to do in the engine. There is enough there to say the HPT is going downhill and the core is following it. Probably the best thing to do is to change out to the core and HPT. However, what I don't have is enough information to match my component changes with other available parts, to get some more life out of it. So maybe another call to the computer would give you an economic analysis of maintenance on the engine. You need something to indicate what additional TRIC's to run to get that information. It should give you the economics of this

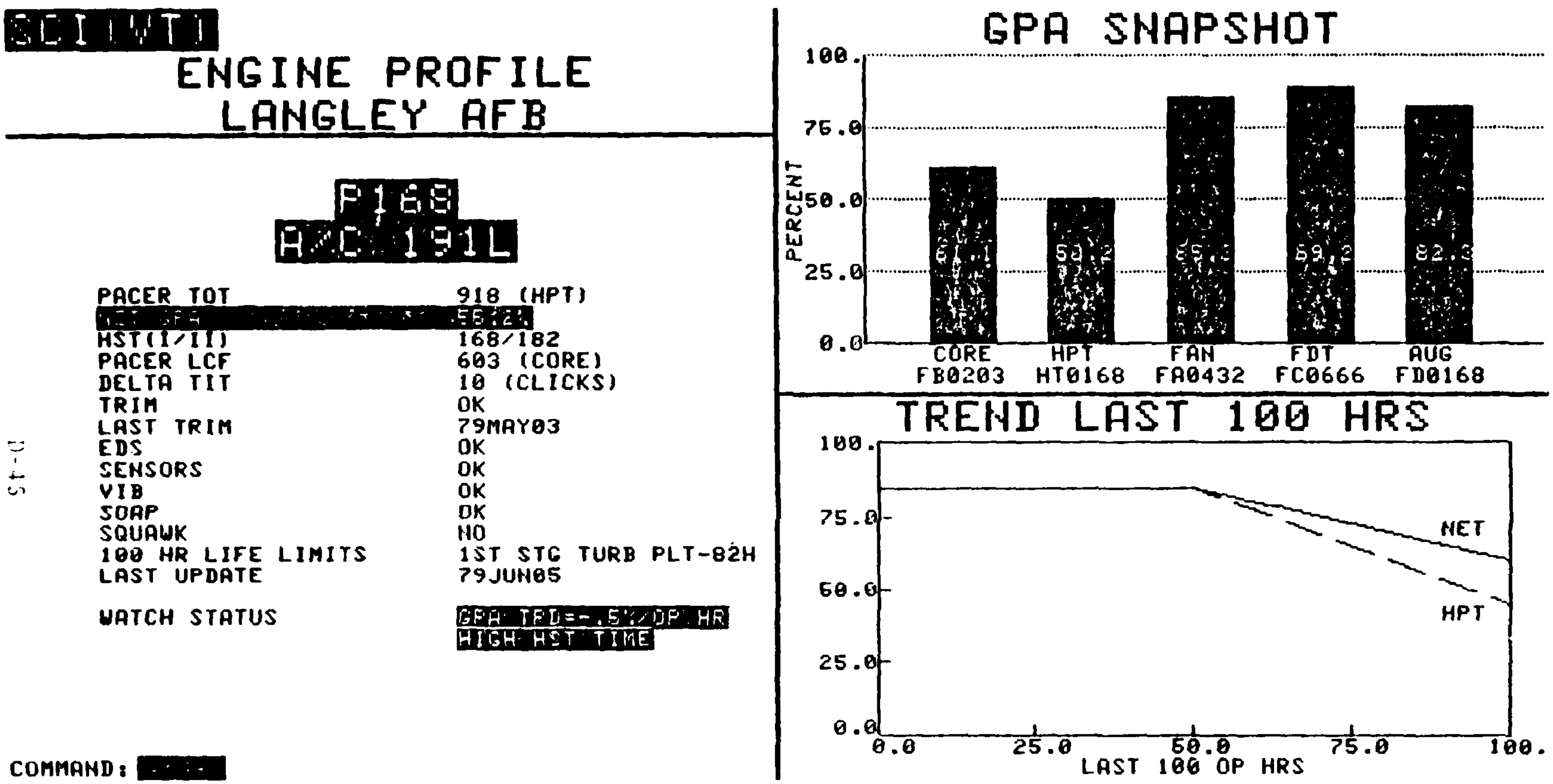

Figure 6 Profile, Snapshot and Trend of Engine on Watch Status for Performance Reasons

maintenance action: do I want to let it continue to fly out
Om its 82 hours at a .5 percent degradation rate, or is it more economical to stop that deterioration right now, because I don't want to burn the thing out completely.

M: What units do you measure that in?

B1: You would measure that using GPA to indicate the condemndation rate is going from 2% to 50% in a period of time. That still leaves the determination to fly the aircraft out at the DCM. He may say he can afford to throw parts away because there's more economy in flying the next 40 missions.

M: That's an excellent suggestion.

B1: You should have a border line across 25% or whatever that number is, to indicate this.

M: Suppose I swap one module, how does the GPA recover? Is that a useful question to answer?

Tn B1: And what is the new trend for the next 100 operating hours.

M: How far ahead would you need to forecast?

Fo B1: To the next scheduled or life-limited point in the engine.

M: You want the ability to run that for a number of different component combinations?

D2: There is a tremendous amount of flexibility in that. Depending upon when the next scheduled event is, whether it is a time/temperature event or a phased inspection, you could change
Fo something that would still keep that engine on the aircraft until you get to a phase, and fix it up then.

M: You must know when the next event will occur.

D2: You know when the next hard schedule maintenances are going to occur.

M: "Hard schedule"?

D2: The phases and those types of activities. You know when they're going to schedule the aircraft down for water washes. You can correlate time/cycles to parts consumption. If we know
Ms what module is contributing to our performance degradation and to what degree the various modules do contribute, the question is: "What could I do within a reasonable period of time to keep that engine flying?" Maybe you don't want to pull out a whole core or compressor. If the compressor is the biggest item contributing to the performance degradation and the fan is also contributing, it may be easier to change out a fan than to change out a compressor. That could change your GPA to an acceptable level. You could keep the engine on the wing for another 100 hours, and then fix it up at its phase. You may have prevented complete engine removal.

M: The key issue is the integration of all these factors.

D2: Previously, they would have pulled the engine out and maybe
Ga sent it to depot.

4.8 <u>Engine Profile - Integration</u> (Figure 7)

M: The next display looks at another profile of an engine on watch status. This engine had a vibration jump. The oil analysis trend shows the rate of change in parts per million per hour. That's a little bit different from the SOAP charting that is normally analyzed. Comments?

B3: When was the SOAP taken?

M: It would have been taken after the last flight.

C1: Why did you choose to show that PPM/Hour, rather than against the established guidelines?

SCI (VT)

ENGINE PROFILE
LANGLEY AFB

P342
A/C 203R

PACER TOT	780.3 (FDT)
NET GPA	81.3%
HST(I/II)	33/21
PACER LCF	431 (CORE)
DELTA TIT	12 (CLICKS)
TRIM	OK
LAST TRIM	79MAR21
EDS	OK
SENSORS	OK
VIB [illegible]	[illegible] MILS
SOAP	OK
SQUAWK	NO
100 HR LIFE LIMITS	NONE
LAST UPDATE	79JUN05
WATCH STATUS	G/B VIB JMP=1.9 MILS MONITOR SOAP

COMMAND:

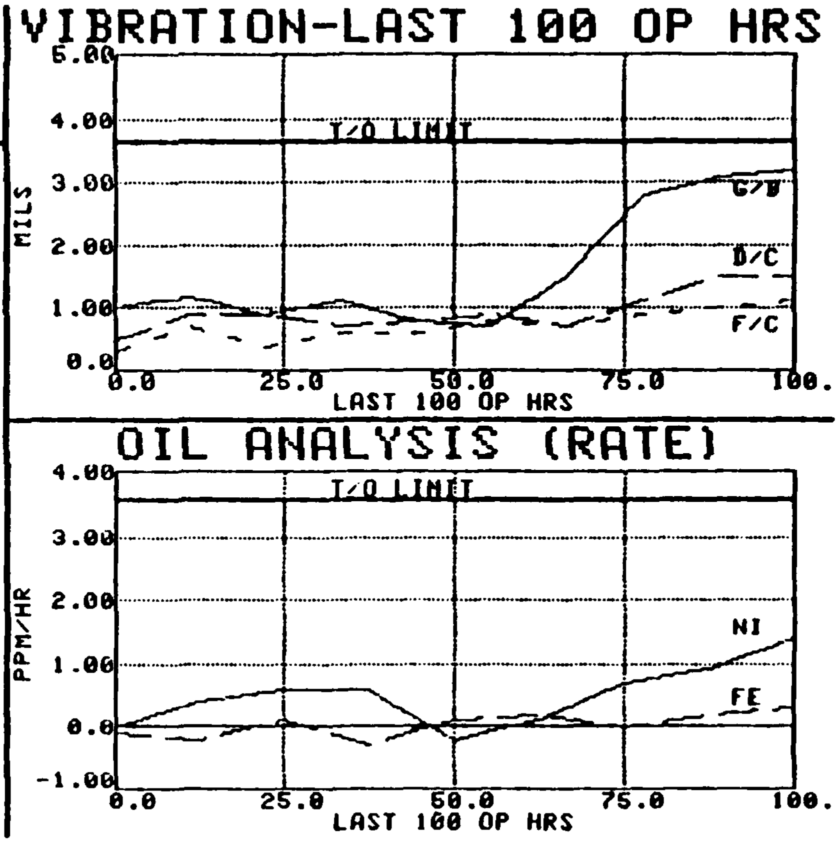

Figure [illegible] Vibration and Oil Trends for Engine on Watch Status

M: A lot of TO's are written in terms of PPM/Hour.

So D1: No, just parts per million. It's the parts per million of wear metal in that oil that you're sampling.

C2: Time is only a convenience for trending. It is strictly a PPM.

M: If you had a certain parts per million level, does that specify a maintenance action?

C2: Yes.

B1: There is a flat limit on parts per million; also, there is a limit that indicates rate of rise.

D1: You have a trend and a threshold. There are two different things you want to watch in SOAP, and those are the trend and the threshold. And if you hit either one, you start doing something.

M: Is the trend parts per million since the last SOAP?

C2: One of them is. I think you could put both SOAP displays on the one chart.

D1: On your F100, for some reason titanium is a critical.

C2: You could plot any of them, but you'd have to be able to put the threshold in for whichever one you were plotting.

4.9 Sorting (Figure 8)

M: The next display demonstrates sorting engine files based
Da on a serial number. This might be used for locating a specific TCTO completion record. The columns are: serial number, status, location, health, trend and clicks remaining, pacer module, hot section time and life limits.

B1: If you had a number of components or modules that were coming up on life limits, would they just continue to display themselves

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BASE STATUS MONITOR

LANGLEY AFB

LAST UPDATE:79JUN05

S/N	STATUS	LOC	GPA	ΔTIT	PACING MODULE	HST I/II	LIFE LIMITS
P100	FMC	122R	94.3	12	HPT- 423.5 HRS	40/23	
P110	SERV	SHOP	99.6	13	FDT 531.6 HRS	14/12	
P113	FMC	125L	80.3	10	HPT- 603.5 HRS	56/10	
P114	ENMCS	SHOP	51.1	4	FAN 654.3 HRS	16/35	
P125	AWM	SHOP	40.2	5	GEAR BOX- 977.3 HRS	23/35	GEARBOX-33H
P126	PMC-AVIONICS	132R	79.9	7	CORE- 822 CYCLES	60/52	900 CYCLE CORE
P127	CANNS	SHOP	43.1	2	CORE 720 CYCLES	12/16	FUEL PUMP-75H

Figure 8 Engines Sorted on Serial Number Attribute

down the columns?

M: On a summary display there would be an indication of 1. You could get the remaining ones displayed.

Lu B1: If there were more than one component or module that was coming up on life limit you should put a TRIC in that column, which would drive the guy to go in there and display it.

M: Would you rather have life-limited components within 100 hours come up, or would you rather just flag a continuation?

B1: If you were looking at a base that had 180 engines on it,
Df what percentage of the engines would fly into the status monitor. I know you could roll it, but would that be the thing that you would want to do?

C1: I could envision circumstances when you would want either/or.

B1: They put the biggest life-limiter up there, which is a fuel pump. They put a TRIC that says, "Now, hit that TRIC on that engine's serial number," and then you get a hard copy of every component.

B2: Is it possible to get a number, like that particular engine has five life items, 10, or 20?

Da B1: That might be a better way to go. In fact, that comment relates to every one of your presentations. If a presentation drives you to go someplace, give him what he should enter so that he doesn't have to look it up on a card or a book or a tech order.

D2: Maybe the first display after you give some documentary information would be index, saying, "Here's what else is available."

B1: No, don't confuse him. Just point him in the right direction.

C2: I don't think you need the index-type thing. I think you just need something there that says, "Hey, you got this information.

If you want more, punch A-2 or whatever." Just give the guy what he needs to know, because he doesn't want to keep going back to an index.

Bl: He ought to line the cursor up under life limits and then hit the TRIC and go forward. Limit the number of entries the

Df guys have to make.

Dl: If we have a wing of 72, we're talking about 160 engines. Are we going to have a roll capability on this?

M: Yes.

Bl: Let me throw one at you. Can the computer analyze the maintenance that has been performed on an engine build, to come up with an indication that this engine is past economical maintenance? In other words, if this engine keeps displaying problems, and keeps forcing us to do maintenance on it, over and over again, that is when we have reached the economical limit. We want to send the whole engine back to get it completely restructured.

Dl: Let me address that. OCM is going to look at that engine and only fix those things that need to get fixed to bring it back up, and you're going to get it right back.

Md Bl: Absolutely, and I think that's a good way to go about it. But, if we get an indication that, "Hey, we've reached a point where this engine is completely wasting our money and wasting your time, becasue every one of those components is going to come back to you and get recycled." It's just a non-economical engine. We need to alter that build in some way or another. You know, that type of analysis against the engines to say, "Hey, guy, you're just spinning your wheels on this engine, pull it out of there and do something with it."

4.10 Grouping Capabilities

M: The next set of displays shows the health of a squadron at one point in time (Figure 9). You would be comparing the current Gr health with the health at another point in time. It is a snapshot comparison between the two dates (Figure 10).

B2: The range would be in GPA?

M: Yes, in this case, we are looking at performance.

D1: Something else I'd like to see would be the left and right engines alongside one another.

M: The capability would exist to do a snapshot on any subset. For example, a snapshot of left engines on the left side and right engines on the right side.

B1: I'm trying to figure out what that's telling me. What am I going to use that for?

B2: You'd probably use that up at headquarters to see if the guys are washing the compressors down at the local base.

D2: No, you can use that at the squadron.

C1: That's just to look at fleet performance.

B2: Well, I wouldn't need that down in the AGS.

B1: It doesn't show me movement in performance. It doesn't tell me how many total hours I've flown, it doesn't display the sorties flown, it doesn't display the type of sorties flown.

D2: It tells you squadron-wise you've had a significant degradation of performance over the period.

B1: Is that significant or is that normal for what I've been doing with those airplanes? That's what it doesn't tell me. It just gives me some numbers and I don't know what to do with the numbers.

M: Going into this, you will have some knowledge of the mission being flown, in terms of total operating time or sorties.

B1: Cumulative missions on any group of aircraft--it needs a

BASE STATUS MONITOR ΣDI(VT)

LANGLEY AFB

LAST UPDATE:79JUN05

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79JUN05

	- GPA	FACTOR -		
RANGE	NET	CORE	HPT	FAN
90-100	3	2	3	15
80- 89	4	2	5	10
70- 79	6	6	7	7
60- 69	9	9	8	4
50- 59	8	10	9	0
40- 49	6	7	4	0
TOTAL	36			

Figure 9 Grouped Display Show Squadron Health (79 JUNE 5)

BASE STATUS MONITOR SCI(VT1)

LANGLEY AFB

LAST UPDATE:79JUN05

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79JUN05

RANGE	NET	CORE	HPT	FAN
	- GPA		FACTOR -	
90-100	3	2	3	15
80- 89	4	2	5	10
70- 79	6	6	7	7
60- 69	9	9	8	4
50- 59	8	10	9	0
40- 49	6	7	4	0
TOTAL	36			

ENGINE GPA SNAPSHOT
SQUADRON 119(F15)
79APR19

RANGE	NET	CORE	HPT	FAN
	- GPA		FACTOR -	
90-100	18	16	17	30
80- 89	16	17	17	6
70- 79	2	3	2	0
60- 69	0	0	0	0
50- 59	0	0	0	0
40- 49	0	0	0	0
TOTAL	36			

Figure 10 Grouped Display Comparing Current Health Rating (79 JUNE 5) to Past Performance (79 APR 19)

computer. I could never be that knowledgeable.

M: The question is, is there a function that this display could address. Does anybody have a use for this display?

Ms B1: There is a use relative to scheduling the remaining life in your fleet, if you knew what the levels were related to.

M: What do you mean?

B1: Suppose I did air-to-ground missions during the period. When I started I knew the performance or health of my fleet. Afterwards the health of the fleet has deteriorated. I still have life left remaining, and I need to know how much. By changing the mission that I'm flying next month, I could take advantage of this knowledge.
Fs It also gives me data that I would use, to determine that I'm getting a lot of engines that are going to be coming out for maintenance all at once. I want to do something now to segregate these, and find out which are falling under that category so I can not fly some, or fly some faster. That's the type of information you could use, but there is just not enought to direct me to ask the computer the right thing.

B2: Is there any information available on each engine snapshot?

M: Yes, but you'd have to go through 36 of them and tabulate them to find out that your whole fleet was going downhill.

B1: From something like this display, my next TRIC would give me a movement in time. In other words, where do those figures fall at a particular point in time? I need to know where all my work is going to hit me, at what point in time.

M: The next display (Figure 11) is a bargraph representation of the same information.

B1: I can use the information at MAJCOM, but not at squadron.

Df M: We've actually got those coming up later.

D2: I would say that from a readiness point of view, which is

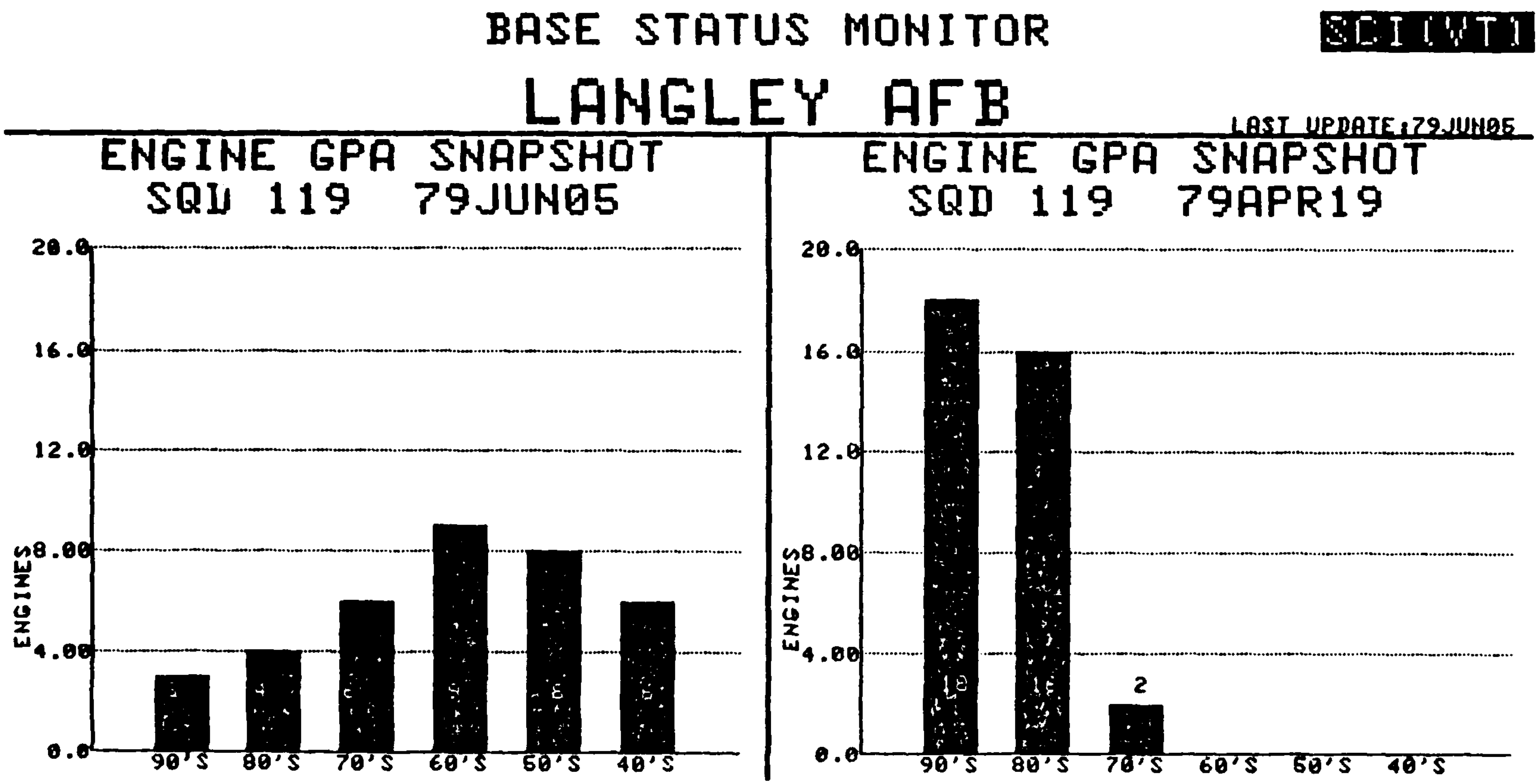

Figure 11 Bargraph Display of Squadron Degradation

what everybody actually is talking about, this is important to look at.

4.11 Ranking Capabilities

M: The next display (Figure 12) shows a rank of all engines on a nonstandard attribute, ranking all fans whose total operating
Ra time lies between certain limits. Standard pieces of information and information on the fan, serial number, etc., are obtained.

B3: Why do you need delta TIT?

Df M: It is used in the standard presentation. You may not use all of those pieces of information.

B2: Can you put the title on these displays?

M: Indicating what was sorted? Okay. That's it...

B2: All the Airmen First Class will be doing this thing.

M: Looking at the next display (Figure 13), you want to rank your engines according to joint health.

B1: When Plans and Scheduling comes down with some recommendations and you have the ability to look at this, you'd like to see it.

Ms B3: Yes, but the DCM makes the decision.

M: But somebody needs to know that there is a 900 cycle core due in 82 flight hours.

B1: You've been looking at Langley AFB, right?

B3: They do that all the time; they swap engines out.

B2: We're scheduled for deployment, then we say, "Hey, we have to change this one." You're going to take away our most effective way of changing cores.

M: Would that capability make sense?

All: Yes. (consensus)

BASE STATUS MONITOR

SCI(VT)

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LAST UPDATE:79JUN05

FAN TOT	FAN S/N	S/N	STATUS	LOC	GPA	ΔTIT	HST I/II	LIFE LIMIT
85.3	CA0672	P288	FMC	189R	88.3	10	33/54	
101.4	FA0684	P461	FMC	195L	91.3	11	88/42	
102.9	FA0691	P691	FMC	209R	85.4	8	91/81	
125.7	FA0693	P202	FMC	255L	89.9	12	16/22	
191.3	FA0803	P335	FMC	262R	82.3	9	44/33	

Figure 12 Ranked Display of All Engines with FAN TOT < 200 Hrs.

SCI (WT)

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LAST UPDATE:79JUN05

JOINT GPA	A/C	STATUS	S/N	GPA	ΔTIT	PACING MODULE	HST I/II	LIFE LIMITS
98.7	131R	FMC	P162	98.3	12	FAN -666.1H	101/97	
	L		P141	99.1	10	FDT -703.1H	91/88	
97.8	156R	FMC	P216	97.0	8	CORE-303C	61/55	
	L		P203	96.4	10	HPT -661.2H	72/66	
96.3	119R	FMC	P414	96.4	12	CORE-509C	99/55	
	L		P192	96.2	10	FDT -303.2H	66/33	
94.8	172R	FMC	P149	95.3	8	FDT -451.2H	51/61	
	L		P165	94.2	11	CORE-801C	102/66	900C CORE-82H
93.5	141R	FMC	P281	94.9	12	FAN -804.2H	97/43	
	L		P334	92.1	10	FDT -801.3H	78/51	
92.4	162R	FMC	P188	94.6	9	FAN -404.9H	72/66	
	L		P156	90.1	8	FDT -667.3H	66/33	
90.7	191R	FMC	P431	92.3	12	HPT -309.2H	32/41	
	L		P501	89.2	12	FDT -303.1H	43/31	
90.7	181R	FMC	P602	93.1	10	FAN -603.5H	62/17	
	L		P341	88.2	9	FDT -402.1H	54/18	
90.3	203R	FMC	P319	90.3	11	G/B -902.1H	98/101	GEARBOX-98H
	L		P333	88.2	11	HPT -556.9H	42/51	
88.7	137R	FMC	P122	89.3	10	FAN -303.1H	56/66	
	L		P262	88.2	9	FDT -492.7H	61/71	

Figure 13. Ranking Aircraft By Joint Engine GPA

B2: This is going to pinpoint pilots, too.

D1: I don't know. You could have one sick one and one good one and you're going to...

C2: Swap engines.

B1: Explain JOINT GPA.

M: It's an average of the two engines installed on the aircraft.

Ga B1: My only suggestion would be to take a look at the pacing GPA. You've got a pacing module, now display a pacing GPA.

M: What about eliminating HST?

D1: That's the first time it has come up, so evidently there's nobody in this room that's really concerned about it.

B1: HST? No sir.

Lu D2: The parts-tracking people are interested in that.

B1: No, that's a diagnostic TRIC.

D1: My comment is that I haven't head any comment about HST.

B1: It's a diagnostic tool, rather than a limiting tool.

M: It's correlated to the current HPT.

B1: You don't need STATUS.

M: Those engines and aircraft are all fully mission-capable.

D2: JOINT GPA does disturb me. You just take two numbers and average them.

M: It's just used for ranking.

B1: Why not use the JOINT GPA without displaying it?

D2: I don't think JOINT GPA is a valid number base on the theory.

M: You don't want to deploy an aircraft with one good engine and one degraded one.

D2: I think your probability is greater of doing that by zeroing in only one GPA figure.

M: Rank them by JOINT GPA, but don't present it. Let the people look at each GPA separately.

C1: One other point, before you decide to eliminate the STATUS column. It's not inconceivable that you'll have airplanes with excellent GPA but which will need fire control work for weeks.

Md M: There are other reasons for not being FMC.

C1: If nothing else, it's a source of good engines.

B1: Yes, it is a source of good engines.

M: The next display (Figure 14) shows the status of uninstalled engines.

B1: Instead of a SUPPLY column, put in a MAINTENANCE AND SUPPLY problems column.

Su C1: Or just PROBLEMS. The percentage number doesn't have any real relevance unless you know about the job, i.e. in terms of planning how long it's going to be before it comes through.

M: You want an indication of the problem?

B1: Yes, is it a waiting maintenance. Of the three there might be long or short ones.

B2: In the ENMCS, I feel you need that documented. You should interface with the supply computer. This would be perfect, especially for uninstalled engines. Why should the guy have to
Ba go to three or four different computer products to get the whole story? If we're going to use this BASE STATUS MONITOR, then I think you ought to equip the system to handle the supply documentation. The ENMCS is 119 data product. You should print out supply document number.

B1: Make a separate TRIC to display document numbers.

M: By document number, is that the part number for supply?

B1: It's the requisition number for that supply problem.

B2: You definitely need those, so you can say it's 40% ENMCS.

BASE STATUS MONITOR

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LAST UPDATE:79JUN05

UNINSTALLED ENGINES

S/N	STATUS		SUPPLY PROBLEM	LOC	GPA	ΔTIT	HST I/II	LIFE LIMIT
P110	SERV	100%		SHOP	99.6	13	14/12	
P142	SERV	100%		SHOP	99.5	10	22/13	
P208	SERV	100%		TEST CELL	99.8	8	101/89	
P139	MAINT	60%		SHOP	76.3	11	88/72	
P154	MAINT	30%		SHOP	44.3	6	44/32	
P222	MAINT	50%		SHOP	82.3	10	55/44	
P303	MAINT	90%		TEST CELL	58.2	11	61/29	
P421	MAINT	40%		SHOP	69.3	5	33/42	
P125	AWM	10%		SHOP	48.2	5	23/35	GEARBOX-33HR
P521	AWM	10%		SHOP	61.3	8	92/81	
P606	AWM	10%		SHOP	52.1	11	105/88	FAN DUCT-80 HR
P119	ENMCS	40%	3RD STG TURB DISK	SHOP	51.1	4	16/35	
P127	ENMCS	40%	3RD STG TURB DISK	SHOP	43.1	2	12/16	FUEL PUMP-75 H
P617	ENMCS	80%	CNTRL EXH NOZZLE	SHOP	80.3	10	35/62	
P702	ENMCS	80%	CNTRL EXH NOZZLE	SHOP	44.3	10	88/39	

Figure 14 Status of Uninstalled Engines

In reality, it may only be 10% as far as completing the engine; it's 90% built-up. It has 10% to go, but it has eight parts on order. All these parts are minor parts, that can be put on within 3-4 hours, whereas another engine will only need two parts but it's
Su way inside the engine and the whole engine is being held up for them. So if you really want to help that guy out, you need those supply documents.

M: This morning, we eliminated the percentage on ENMCS.

C1: You don't want to eliminate it in this case, because it tells me where that engine is in the maintenance cycle.

B1: But, again, you don't know what maintenance cycle it's in, so 40% is relative to nothing.

C1: We'll know what the problem is.

B1: The supply problem is the existing problem. You wouldn't have the maintenance problems built up, yet.

Ms C1: The estimated man-hours to complete is more significant than the percent.

B1: That's right. It's the backlog that will exist when you get the supply problem satisfied. You still don't know when the supply problem will be satisfied. The other computer has that information.

M: By giving the requisition number, you could access that part?

B1: So, if it's a supply problem, we don't need to see third-stage turbine disk. What we need to see is "six parts EDD 2 June."

C1: You need to display only the parts that are problems. You may have 40 parts on order, but you may have satisfactory delivery dates on 39 of them.

M: Okay.

C1: And as far as the percentage versus man-hours, I don't think it makes a lot of difference. Be aware of how the units are doing today. The shops I've been associated with deal in percent complete. And if you go to man-hours, you may be imposing another task on them to keep that current.

M: Does anybody from Langley AFB look at it in terms of percent complete?

B3: We always consider work order status in percent. The only time it's different is when you're figuring a backlog for TAC.

C1: If you know what the problem is, and you know what the percentage is, that automatically translates to man-hours.

B2: I think 400-1 (AFM 400-1) and also the other Regs specify in-shop cause in percentage; when you're rating the engine as far as how close it is to being FMC, it's in percentage. And when we're talking about problems at a given base at command level, we're talking about man-hours.

M: So, at this level, the percent would be acceptable if you specified the problem?

B2: Yes, if you specify the problem.

4.12 Deployment (Figures 15 and 16)

The next group of displays will address deployment. This capability was originally envisioned as a command level function for multiple based deployments. Survey results indicated it should be a base-specific function. You go through

De a procedure that would be the same as making your own decision. Any comments?

B1: Any time you put that thing in a computer-accessible area, you're going to have to make sure your whole computer area is secure.

M: It would list (Figure 16) based on joint GPA, your eligible aircraft. We indicate that, based on the condition of these engines, you should bring four spares along and you are shown two additional engines to replace those that have life-limited parts.

B1: I have to know what parameters the computer was making the decision on. They may not be the same parameters that we would make that decision on. It's good information to have.

M: Would you prefer this method or the procedure shown in Figures 13 and 14, i.e. ranking the engines?

C1: I think that's the whole point. This display is redundant.

M: Does it make sense to provide a deployment planner? Would there be any payoff?

B1: Knowing the rationale that went into it, how you reached those specific numbers, would make it more acceptable.

M: This is a computerized decision process and it may not be entirely accurate.

B1: Most deployments require a configuration of an airplane, so the airplane tail number gets set, period. You should trust

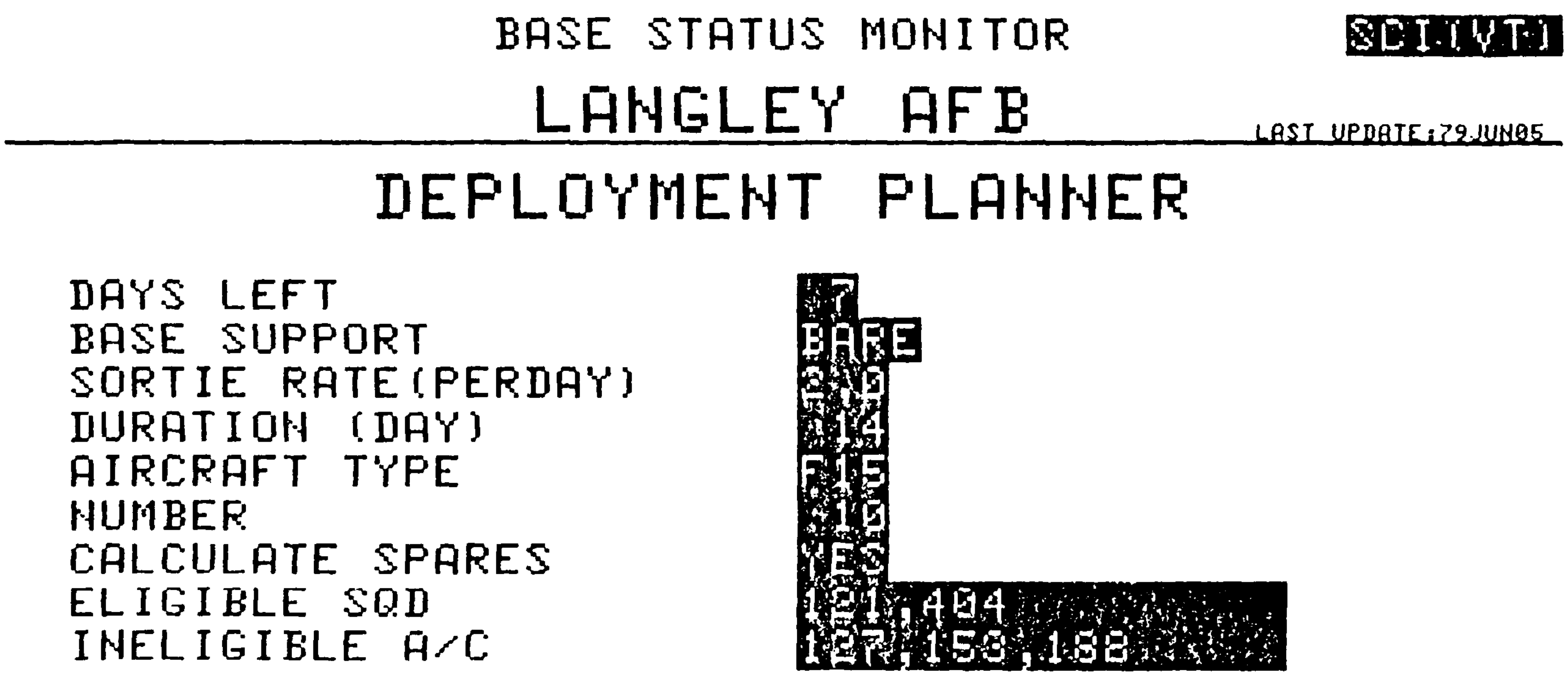

Figure 15 Input for Deployment Planner

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LAST UPDATE: 29JUN05

AIRCRAFT

A/C	SQD	S/N L	S/N R
131	121	P141	P162
156	121	P203	P216
119	404	P192	P414
172	121	P165	P149
141	404	P334	P281
162	404	P156	P188
191	121	P501	P431
181	121	P341	P602
203	404	P333	P319
137	121	P262	P122

SPARES

4 ENGINES REQUIRED TO SUPPORT DEPLOYMENT

S/N	LOC	STATUS
P110	SHOP	SERV
P142	SHOP	SERV
P208	SHOP	SERV
P303	CELL	MAINT-90%
P404	127R	SERV
P621	153L	SERV

P165, P319 UNABLE TO SUPPORT SORTIE SCHEDULE, REPLACE WITH TWO OF ABOVE

Figure 16. Sample Output from a Deployment Planner

the aircraft tail numbers and possibly some alternatives. The
Md output would be engine information as we have here; can we do that deployment with what we have installed in those airplanes; if not, here are suitable substitute engines.

M: If you are going to deploy 10 aircraft, you get a listing of 10 that will go?

B1: The type of mission you are being deployed for may generate the tail number of the aircraft, depending on what avionics are on-board. You may not have too much choice of the aircraft you deploy. Now we have to go into a planning situation. We have to know, "Will those engines last on those deployed aircraft?"

M: The inverse video could indicate areas where you should look further?

C1: Does the fact that those aircraft tail numbers are listed there imply that they are fully mission-capable?

M: Yes.

C1: I see an awful lot of problems, particularly since the FMC status changes hourly. I have a lot of trouble with that.
Md I'd end up resorting to the manual system. I'd probably want to go through and look specifically at engines.

M: As it was in the first two displays?

C1: Yes, after I selected my aircraft tail numbers, look at the engines in those airplanes to see whether they were acceptable for the deployment.

4.13 Maintenance Forecasts

The next display is a monthly report, based on accumulation of time and cycles. You would be interested in forecasting

Fo to an estimated removal date. This display correlates with the general health of the engine (Figure 17).

B3: What is the margin on that GPA?

M: Type of limit? Based on the current health and the degradation at a particular rate, we predicate the unacceptable performance date. It is difficult, without operational experience, to set a margin. That prediction is based on the current time and on the trend. It's a prediction. If the usage rates of the engines significantly change, it will be wrong.

B1: Can you examine your whole fleet as percentages; which are affected by cores; which are affected by fans; which are affected by components?

M: Do you want this in time and cycles as well as health degradation?

B1: Time/cycle degradation. If you have a bell curve, you
Df know what percentage for any period of time is going to be driven by fans, cores, HPTs, and components.

M: Would it be used more at a command level or at a base level?

B1: I can see it being used at all three levels: depot, base, and command. It's a different scope at each level.

M: What is the forecast interval?

B1: Six-month forecast is the standard you should go to.
Fo The depot would rather see something like a two-year forecast.

C1: Can we call it up that way? Can I ask for all engines that are going to come up for cores?

B1: Any time there is information like this, you can go in on any single element.

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LAST UPDATE:79JUN05

TIME/CYCLE REMOVALS

S/N	LOC	DATE	BALANCE	COMPONENT	GPA
P206	149R	79JUN22	15.3H	CORE-TCTO 900C	79.9
P921	351L	79JUL09	34.3H	1ST STG HPT BLADES	75.6
P694	263L	79JUL19	130 C	FAN: DISK	44.2 (JULY 79)
P777	404R	79JUL22	152 C	1ST STG AFT COOL PLT	72.3
P381	621L	79JUL24	62.1H	1ST STG HPT BLADES	75.4
P707	279R	79AUG11	179 C	1ST STG COMPR DISK	57.2 (AUG 11)
P603	188L	79AUG15	189 C	FAN DISK	43.2 (JULY 79)
P903	199L	79AUG22	91.1H	1ST STG HPT BLADES	74.3
P822	299R	79AUG24	93.2H	1ST STG AFT BLADES	79.1
P471	411R	79SEP07	222 C	FAN DISK	58.1 (AUG 79)
P801	199L	79SEP08	223 C	FAN DISK	64.1 (SEPT 79)

MORE?

Figure 17. Forecast of Time/Cycle Removals

B1: What we should be able to do is go from any direction we
Da want, like cores, and what percentage of cores are going to come out for time, cycles, and for degradation.

M: How about a tabular list?

B1: I don't think for planning purposes that tabular gives you information. I don't say do away with tabular. An addi-
Df tive to your tabular information would be a graph, a distribution over time.

M: That capability is one that is essentially available, it's a matter of how it would be implemented.

B1: I can do it now on the existing computers.

M: This display (Figure 18) correlates GPA-predicted removals with the time/cycle removals.

D3: Is the primary reason for the engine being displayed, the trend in the GPA calculation?

M: If you had a very high GPA but it's falling very rapidly, you'll predict that you are going to need maintenance sooner.

D3: What's the breakoff point?

M: This is a forecast of when it will reach the point when it's going to need maintenance.

D3: Say you had an engine with a high GPA, a new engine out of depot, with something rapidly going and it was going down -.5% per operating hour. Would that come in here?

Ga M: Yes, it would appear as an early removal data, even though it was a new engine; that would flag it.

B1: Something like that though should be flagged as an alert.

M: Yes. If the GPA is changing greater than some rate or if it jumps between two measurements, that triggers a watch status.

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LAST UPDATE:79JUN05

GPA PREDICTED REMOVALS

MONTH	S/N	LOC	GPA	TREND	TIME/CYCLE
JULY 79	P168	188R	59.2	-.5%/OP HR	1ST STG TURB PLT (79SEP22)
JULY 79	P555	111R	60.2	-.4%/OP HR	
JULY 79	P603	188L	43.2	-.3%/OP HR	FAN DISK (79AUG15)
JULY 79	P707	279R	45.6	-.2%/OP HR	
JULY 79	P694	263L	44.2	-.2%/OP HR	FAN DISK (79JUL19)
AUG 79	P703	303R	57.2	-.3%/OP HR	1ST STG COMP DISK (79AUG11)
AUG 79	P471	411R	58.1	-.3%/OP HR	FAN DISK (79SEP07)
AUG 79	P506	192L	60.3	-.2%/OP HR	
AUG 79	P421	188R	61.1	-.3%/OP HR	
SEPT 79	P833	195R	63.2	-.2%/OP HR	
SEPT 79	P607	168R	63.2	-.2%/OP HR	
SEPT 79	P801	199L	64.1	-.2%/OP HR	FAN DISK (79SEP07)

MORE?

Figure 15. Forecast of Removals Driven By Performance Degradation

D3: What kind of limits are fixed? For instance, I think you may have a -.3% without any problems. We had that with newly overhauled engines.

B1: You can display this as a total fleet average percentage in degradation. In other words, 10% of the fleet degrades at 2% per hour. You can track it over the months to find out the environmental effects and mission scenario effects against particular degradation.

D1: If you had a norm or an average there in that trend...

M: The trend is based upon a series of data. It's not the slope between the last measurement and this measurement.

Hd B1: I hope that history starts at Day 1 and continues from Day 1. I hope it doesn't end at Day 30 and start all over again.

M: The real question is, "How do I do this for a fleet of engines?" You have to look at an operational fleet of engines and monitor them for awhile to look at an operational fleet of engines and monitor them for awhile to get some experience on the threshold levels and what the levels of a healthy engine are vs. an unhealthy one.

B1: That probably is good from a base standpoint. When you move it up to a command, I couldn't afford to go through every engine that I own and try to look for trends or even have them
Df ranked by trend or ranked by GPA. What I need to have displayed is percentages of movement over the total or a period of time. I would like to know what I was doing with that portion of the fleet during that span of time that generated that trend.

M: Is that a depot or command level monitoring function?

B1: It would be a command monitoring function and it would be an interest item at depot. If they could phase their procurement to the cycles of events ...

L2: We need two years.

B1: I really need forecasting ability for something like that. You just need to change it around a little bit. I would like to add cumulative GPA movement within mission type flown.

Tr

M: So, for example, on P-168, which would be in with a number of other engines that were flying the same mission there would be a column that indicates a drop at -5% per hour while the rest of the population is dropping at -1% per hour.

B1: That would flag the <u>individual</u> engine relative to experience.

M: That's a good suggestion.

B1: In the command level, it would also allow us to forecast the drop out that we should expect if we fly that scenario in an undeployed area.

4.14 Monthly Distribution

M: The next display (Figure 19) shows, on a monthly basis, the distribution of all the engines assigned to a base. You can look at the particular engines within each bar on the next display (Figure 20).

Gr

B1: For this type of a status, I don't see any reason to have clicks. I don't need to see location. You need to see cycles or hours.

M: In terms of a component that was pacing?

B1: No. Do you have an overall chart that gives the pacing module and gives you the serial number of the engine?

M: Yes, one response is that this type of display is not appropriate.

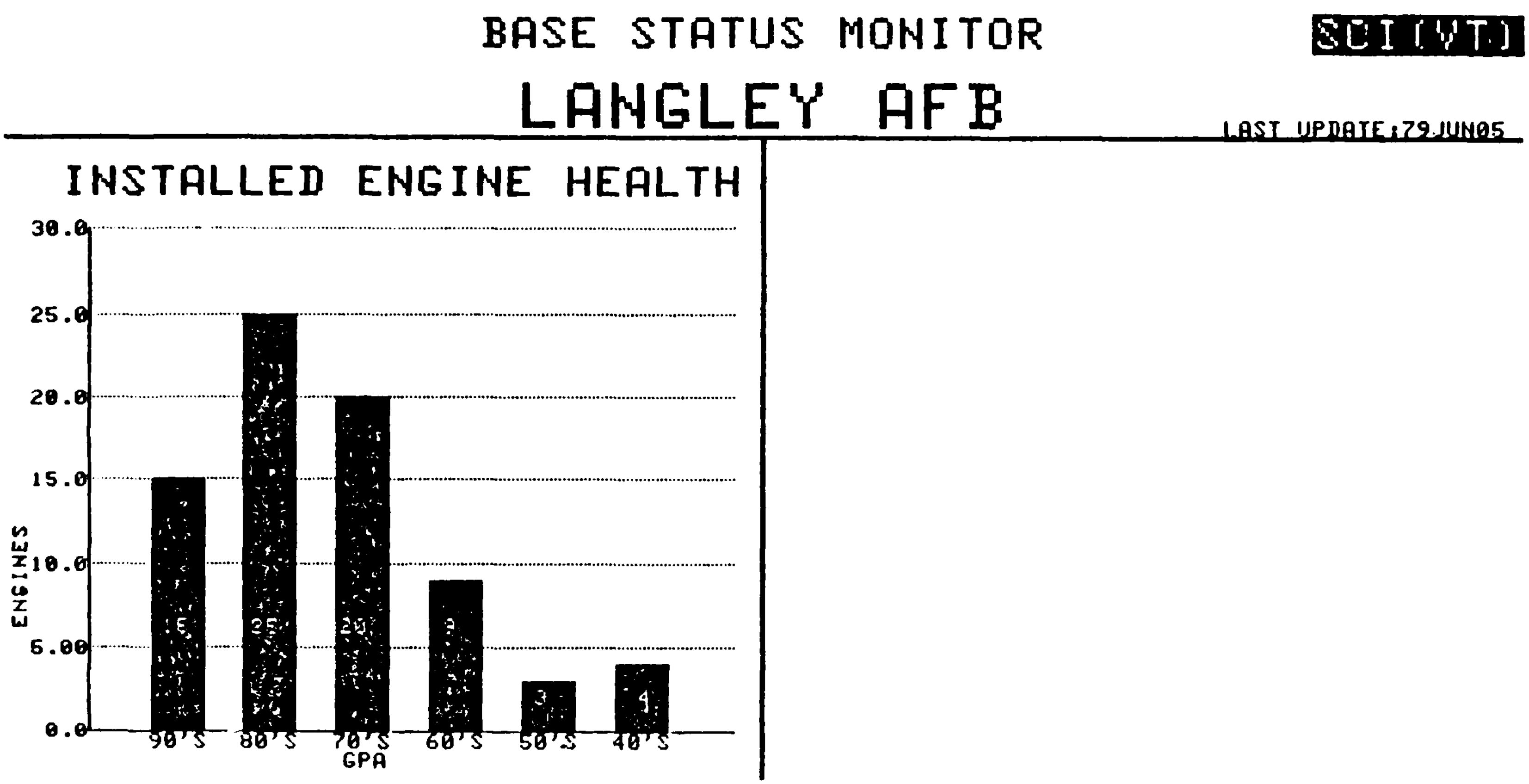

Figure 19 GPA Distribution of all Engines Assigned to a Base (e.g., Grouped Display)

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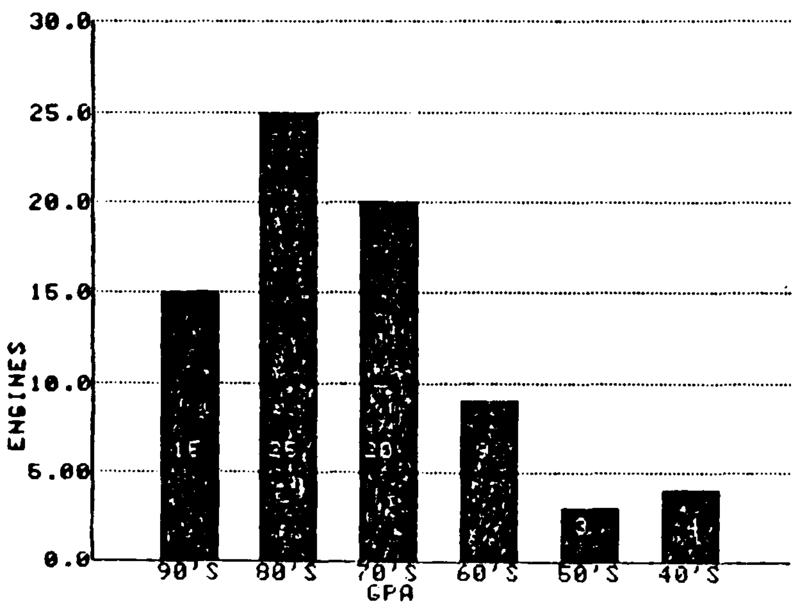
LAST UPDATE:29JUN05

INSTALLED ENGINE HEALTH



S/N	LOC	GPA	ΔTIT	HST I/II
P555	111R	60.2	7	66/32
P506	192L	60.3	8	101/33
P421	188R	61.1	10	72/56
P833	195R	63.2	9	42/40
P607	168R	63.2	9	68/33
P801	199L	64.1	11	91/39
P606	205R	65.3	6	88/72
P704	621L	68.2	5	99/80
P831	345R	69.5	10	62/33
P469	688L	69.6	11	55/61

Figure 20 Access of Additional Data to Support Bargraph

B1: We don't have a display that says installed engines' health, however, we have data on other displays that give us installed engines' health. Based on the question, I would like to see an indicator of whether it was spare or installed.

Df

M: You are only looking at the health of your installed engines.

B1: I would like to see the pacing cycles or hours.

M: We're trying to search for a group of items that can be provided over and over again. We can implement a significantly more complex set of capabilities if we do that.

Md

B1: I don't think we're getting complex enough for these questions.

C1: Let me ask you (B1) a question: what would drive you to look at the right-hand side of the screen? What would be the reason for doing that?

B1: To find out what is causing my installed engine health to be as it is. I'd want to see that in the overall fleet. And I think depot would like to see that, too, because they are trying to figure out what they should be supporting in their production. More cores this month or more cores for the next half year? Or maybe we should plan on fan-drive turbines.

Df

C1: If you're going to look at this, there are other things you want to find out. How long you can leave it installed? When are you going to have to do something?

B1: Presented on that display should be an indicator of goodness, acceptable goodness. That chart doesn't have any movement to it. It is just a totalling chart.

M: By movement, do you want to see what it looked like last month?

B1: The month before, the present and four months out or something like that. A period at a time to be specified, but
Fo we should be able to look at that past performance and we should be able to take a look back at our requirements, i.e. if I am required every month to enter my training plan or flying program, then you should be able to forecast the GPA. Since you know what I'm flying and you've got a history to say, "If you fly that, GPA deteriorates by that percent."

M: That could be done based upon sufficient amount of historical data from previous flights of that mission.

B1: Can you track the removals based upon performance? In other words, I flew x number of sorties or x number of flying hours and I have had so many removals for cause, for schedule pulls, and for unscheduled problems. I am forecasting this as we go out because I know I'm going to fly this amount of hours and this type of sorties. The result would be the
Gr number of unscheduled engine removals per thousand flight hours and the number of scheduled engine removals per thousand flight hours.

M: Would that be appropriate at the base?

B1: It would probably be more appropriate at the command level, but I still think it can be used at base level because not everybody at command is smart and people like to ask the bases what they're doing. So the guy down there has to have the answer and the easiest way is to give him that information.

Fo B2: The propulsion chief forecasts engine removals with a formula that is already in existence. They predict the number of unscheduled removals. There is a factor for doing that. You'll be touching base with something that is already in existence.

B1: But it could be done a little bit better because now he knows what kind of flying we are going to do. The forecasting we have been doing has been so erroneous that it's not funny. We don't seem to be able to match the forecast with the actuals.

M: How far are you off?

B1: Significantly, sometimes you are on the line and other times you float around 50%.

M: Do you need 80% accuracy?

B1: Of course, you would need better than that. Bases have
Fo really not looked at this type of forecasting. They will forecast on general trend for six months. They can do this by knowing the schedule requirements. Based upon flying this airplane as it has flown and based upon the fact that the engine doesn't come out because of something else. There are two variables here, the forecasting of a schedule on an engine, and saying that engine will never break so it can meet its schedule. Then he is forecasting unscheduled events. He knows there is going to be x number in a month. But that is not based upon what he is flying nor is it based upon the type of flying that month.

M: The in-flight-acquired performance data can make a significant impact on the forecasting.

A1: You're touching upon some really significant stuff here, if we can possibly categorize the flight data.

B1: In February, TAC standardized the mission codes. Now, we are flying a specific maneuver, or training to a specific
Fs maneuver; what changes between places is the envelope which you are flying in. This base at 5,000 feet; this base is at sea level. This range is 50 miles away; that range is 700 miles away.

M: That analysis is appropriate to the central data base analysis.

A1: The data is going to have to be tagged with the mission that was actually flown.

B1: That stuff is in the computer. There is something in the 6510 recording system in the MMICS computer, carried in the DOE report.

D2: How are you going to get that mission code if you are

Ba going to automate all this? How does that black box know what kind of mission is being flown? You're collecting raw data off the sensors of the aircraft. The black box is collecting this information.

B1: One of the blocks is the flight number.

D2: You get a flight number, but the aircraft may have three or four missions. Somewhere you have to hang the mission in that box to go along with the rest of the data.

M: If you have the flight number, don't you know the mission?

D2: No. What I'm saying is that you have to get that into the box.

M: The box is the data acquisition. We have data coming in from the TEMS and data coming in from MMICS.

Fs D2: I don't see it occurring as obviously as you do.

C1: It is keypunched in.

D2: That is what I'm saying. Here we are, collecting this information automatically, now we are going to rely upon critical data which is manually entered.

C1: That is how the pilot's flight time is maintained. That is going to be done regardless of whether we use that information or not.

D2: I just feel uncomfortable because I see a problem developing. You are taking data and somehow later on trying to capture what type of flight that was; whether it was in training or a gun run or a bomb run or something else. You are going to take raw data and hope that it gets into this system; I just don't see it going into place that easily.

B1: I thought that the on-board box was going to interface with the pilot mission.

B2: You are going to have to access the sytem at the debriefing area or in maintenance control.

M: The diagnostic system should catalog the time on the engine, flight number, and so forth so this kind of correlation can be made.

D2: The base schedules a flight; let's call it flight 1 on tail number 111. He is going to fly a mission at 8 o'clock in the morning and he is given a mission. That aircraft records flight 1 and picks up some raw data. Unless that box knows
Fs the type of mission, I don't think you're going to pick up somewhere down stream that at 8 o'clock tail number 111 flew this type of mission. I don't see that happening.

C1: You don't think that it will go back to the base computer for access?

D2: You should input the mission then and there, i.e. flight 1 is a training mission and tag it at that point. We're trying to follow those data products at Myrtle Beach now and it is very difficult.

M: What we're here to determine is the data requirements. The data interfacing requirements are the next step. How you actually do this would be part of the design.

B1: I think it's there anyway.

4.15 Depot/OCM Functions (Figures)

M: The primary depot requirement considered was performing on condition maintenance. To specify maintenance, you'll be given certain pieces of information. There is profile information (Figure 21) that would be similar to the base engine profile. The profile indexes which subsystem summaries to access.

Those of you who have experience with OCM, would there be any difference in the profile information that you would
Oc want here.

D1: The thing that's giving them difficulty now is the lack of documented history, i.e. what maintenance actions took place or what decisions were made at base level to send the engine back and the maintenance history that went along with it.

B2: How helpful were those TREs?

D1: Very little.

M: What about the AFTO 781E form?

Hm D1: The 781Es are gone. If they could get a data product containing the 781E data it would be useful.

B1: We have the computer product on a 781E, it's just a matter of the base transferring it. It has to be done and all 781Es except for pacer engines will be on there.

M: The data product would be run off-line and it would look exactly like a 781E?

Ar B1: There will be no hard copy on a 781E. The 781E data should be transferred to the computer when the engine comes to depot. Any changes that they make in the components at depot must be input to the computer against that S/N. When the engine goes back to the base, the computer transmits the information and it's already re-initialized in the base computer. There really is no paperwork to be done.

SCI (WT)

ENGINE PROFILE
TRANSFER FROM LANGLEY AFB

P106

PACER TOT	832.3 (FAN)
NET GPA	56.3
HST(I/II)	188/152
PACER LCF	681 (CORE)
DELTA TIT	3 (CLICKS)
TRIM	79MAR19
LAST TRIM	OK
EDS	OK
SENSORS	OK
VIB	G/B 4.1 MILS
COAP	HI 3.4 RPM/HR
SQUAWK	YES
100 HR LIFE LIMITS	NONE
LAST UPDATE	79MAY16
DIAGNOSTICS	OVERTEMP-1844F 79MAY15

Figure 21 Engine Profile

Df

D1: We put our 337s and our TRE listings on a big table. We have a planner, a scheduler, a production guy, a quality control guy, and our engineer representative. They sit around the table and they look at these documents. Each has a vote as to what they want to do. What we would like to have is some small product like the 781E. You could reproduce it easily. If you could get it into a five or six part document so each man could have it. They are all going over the same material at the same time. They make the decisions and then they press on to the next one. We do four or five of these a day. When you see four or five cores on an engine or maybe two engines, this takes a lot of time.

M: What about the AFTO 95 form (significant history)?

Hm

B1: By the time the new system comes out, they will be automated.

M: By automated, someone at the base level will sit down at a terminal to key it in?

B1: The history will be divided into the module and accumulated to a total engine. TCTO data is necessary for San Antonio ALC and whether the base shipped the TCTOs with the engine. (Figure 22)

Ar

B3: Depot should like this system. We wouldn't have to ship any paperwork at all.

M: Yes, that's possible. Now, you might want to display the bar graph representation of relative GPA for all the modules (Figure 23) and the trend information.

Df

B1: There should be a second display under the GPA snapshots indicating cycles- hours, and limiting components within a module. That would tell them how far to go on the OCM.

SCI(WT)

ENGINE PROFILE
TRANSFER FROM LANGLEY AFB

P106

PACER TOT	832.3 (FAN)
NET GPA	56.3
HST(I/II)	188/152
PACER LCF	681 (CORE)
DELTA TIT	3 (CLICKS)
TRIM	79MAR19
LAST TRIM	OK
EDS	OK
SENSORS	OK
VIB [illegible]	[illegible] MILS
CORE [illegible]	[illegible] PPM/HR
[illegible]	YES [illegible]
100 HR LIFE LIMITS	NONE
LAST UPDATE	79MAY15
DIAGNOSTICS	OVERTEMP-1844F 79MAY15

SCREENING INTERVAL
REPLACEMENTS

P106

S/N	COMPONENT	BALANCE
ABE02400	FUEL PUMP	160H
AVD30160	COMPRESSOR INLET	168H
XY320155	#1 BEARING	201C
8Z302211	4TH STG COMP DISK	225C
04337124	5TH STG COMP DISK	225C
OKSA3216	VALVE-ANTI-ICING	305H

Figure 22 Screening Interval Information

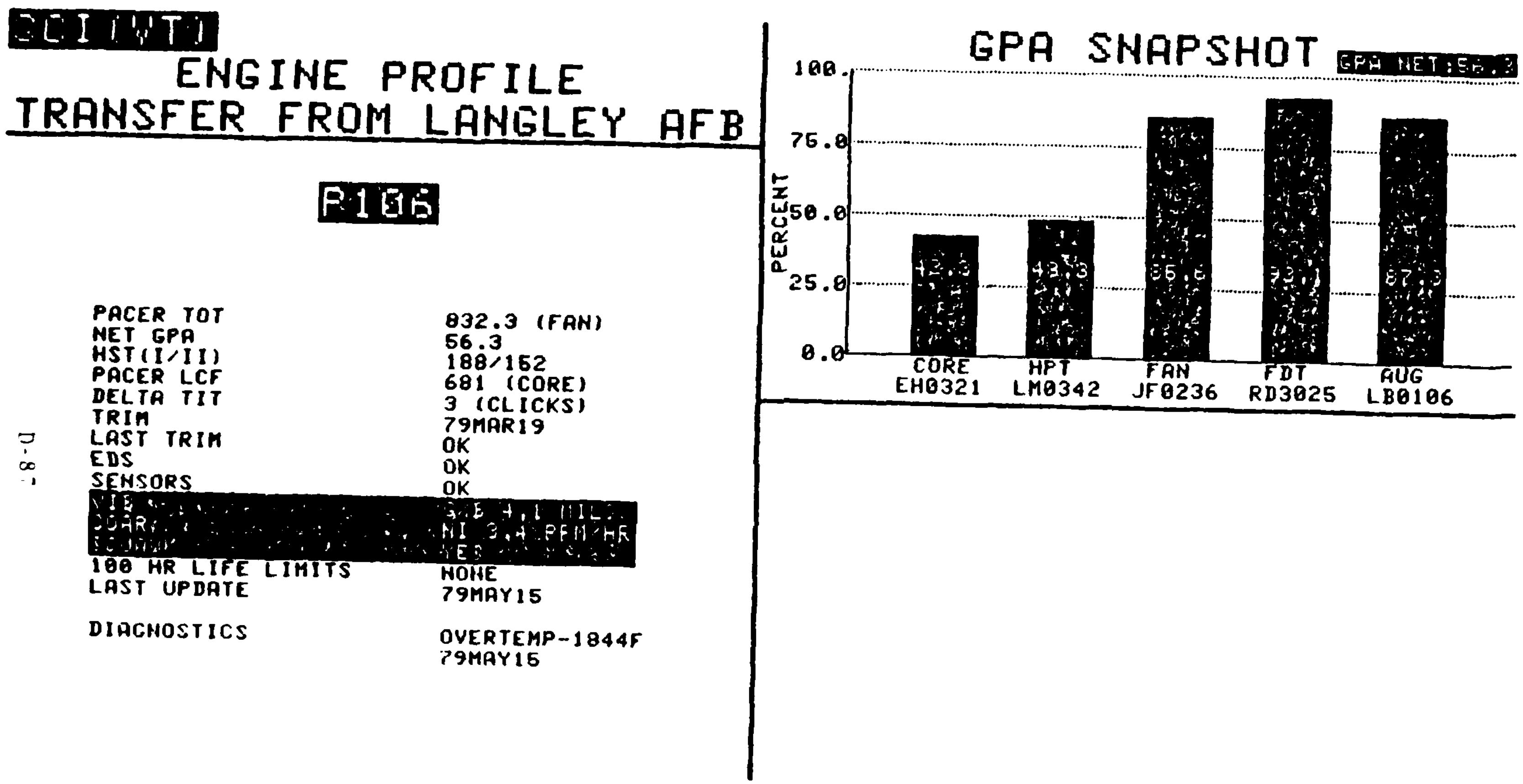


Figure 23 GPA Snapshot

The base would like the display when they got the engine from San Antonio.

M: The next display (Figure 24) shows trended information. In this case, the net over the last 100 operating hours, correlating recent maintenance history. Trended Oil and Vibration data are shown on another display (Figure 25).

D1: That's for engines. Are you going to have a similar display for core GPA?

M: Yes, in the same format.

Hm B1: I think they also need the 1534 (AFTO 1534 form) data that the engine went out under.

M: The removal reason?

B1: Yes. You should run a back history of 1534 on that particular engine or module.

D1: The last entry on your 95 (AFTO 95) is the reason why it's being shipped back to depot.

B1: The engine manager in the MA area has been known to go into the 1534 system and change the reason for removal. He selectively does this primarily when we have removed an engine for cause, e.g. the turbine blew out. However, the OCM team is going to pull TCTO's, so he changes the reason for the removal code to TCTO. You know what that does to us? It makes our unscheduled removal rate very inaccurate.

M: This concludes this discussion for today's meeting.

SCI (VT)

ENGINE PROFILE
TRANSFER FROM LANGLEY AFB

P106

PACER TOT	832.3 (FAN)
NET GPA	56.3
HST(I/II)	188/152
PACER LCF	681 (CORE)
DELTA TIT	3 (CLICKS)
TRIM	79MAR19
LAST TRIM	OK
EDS	OK
SENSORS	OK
VIB	G/E 4.1 MILS
SOAP	NI 3.4 PPM/HP
SQUAWK	YES
100 HR LIFE LIMITS	NONE
LAST UPDATE	79MAY15
DIAGNOSTICS	OVERTEMP-1844F 79MAY15

RECENT MAINTENANCE

ITEM	DATE
1. ENGINE OVERTEMP(1844F)-HIGH VIBS ON G/B-3.5 MILS-STEADY STATE-HIGH NI IN SOAP-ENGINE REMOVED-TRANSFER TO SA-ALC.	79MAY15
2. BORESCOPE-ALL STAGES-MINOR DAMAGE OBSERVED, ENGINE TRIM-3 CLICKS REMAIN	79MAR05
3. REPLACE FDT-INSTALLED RD3025 ON ENGINE P106	79JAN16

GPA TREND

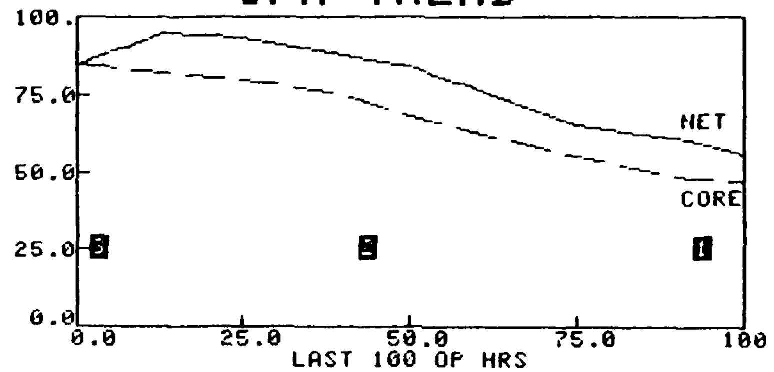


Figure 24 GPA Trend Correlated with Maintenance History

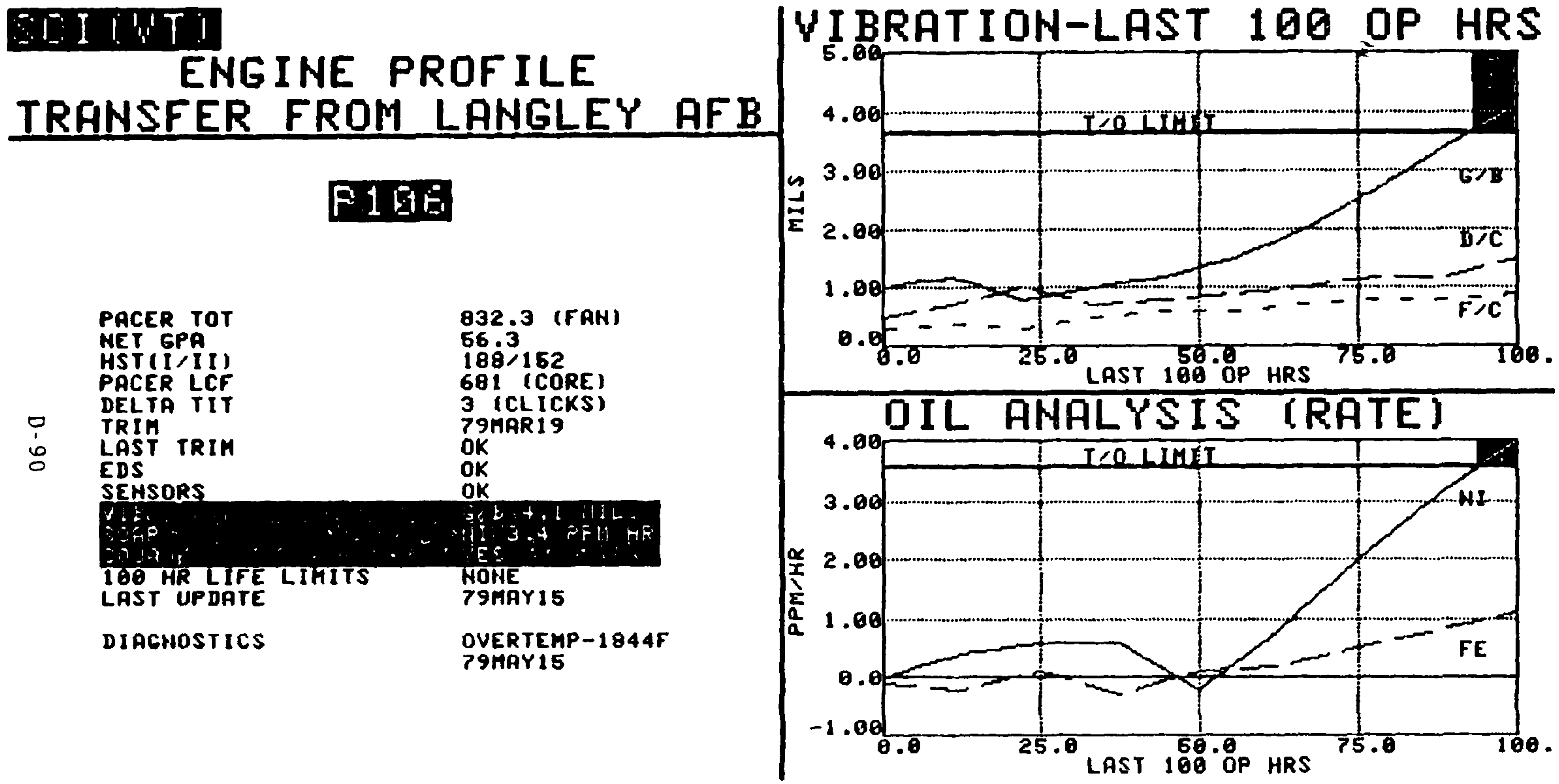


Figure 25 Oil and Vibration Trends for OCM Team

*U.S.Government Printing Office: 1980 — 757-002/221