Transport Canada Aviation   Transports Canada Aviation

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AIRWORTHINESS MANUAL ADVISORY (AMA)

Subject: Reliability Monitoring Programs

1. PURPOSE. This publication provides information on the use of reliabil-ity control methods to monitor the effectiveness of aircraft maintenance programs. Its objective is to provide guidance for the development of reli-ability programs, outline Department of Transport (DOT) standards for the assessment of such programs and give examples of some, but not all, of the statistical calculations and data displays which these programs may employ.

2. REFERENCE AIRWORTHINESS REQUIREMENTS. Airworthiness Manual, Chapter 571 section 571.101 and Chapter 573.

3. APPLICABILITY

(a) The methods described in this advisory are of maximum value when ap-plied to modern, multi-engined, transport category aircraft, which incorporate in their design provision for system redundancy as a safe-guard against component failure. The initial inspection programs for such aircraft are normally based on the mainte-nance steering group (MSG) logic described herein, and may pres-cribe "condi-tion monitoring" (C.M.) as the primary maintenance process for certain com-ponents. In such cases, the establishment by the operator of a system to monitor the reliability of the C.M. components is a condition of the inspection program approval.

(b) Reliability methods may also be applied to types of aircraft other than those described in (a), to assess system and component per-formance for development of the maintenance program, although C.M. may not be prescribed as the primary maintenance process in these cases.

(c) Effective application of statistical reliability methods is usual-ly considered to require a fleet of 5 or more aircraft, although this number may vary according to aircraft type and util-ization. To accom-modate the needs of smaller operators, partici-pation in joint reliabil-ity programs may be approved.

4. BACKGROUND

(a) The first generation of formal air carrier maintenance programs was based on the belief that each part of an aircraft required periodic overhaul.

Times between component overhaul were strictly controlled, and the entire aircraft was periodically disassembled, overhauled, and reas-sembled, in an effort to maintain the highest level of safety. This was the origin of the process referred to as "hard-time".

(b) As experience was gained, it became apparent that some components did not require overhaul on a fixed time basis. Consequently, a second process evolved, referred to as "on-condition". This des-ignation was assigned to components, the condition of which could be determined by visual inspection, measurement, testing or other means which did not involve disassembly or overhaul.

(c) New methods of maintenance control were developed, which were oriented towards the assessment of mechani-cal performance rather than the prediction of failure. These methods were collectively known as "reliability control" because their major emphasis was upon maintaining failure rates below a predetermined value; i.e., the achievement of an acceptable level of reliability. The analy-tical nature of reliability control also disclosed the exis-tence of aircraft components and systems that did not fit either the hard-time or on-condition process categories. This led to the recogni-tion of a third process category in which no maintenance tasks need be specified; instead, current performance is monitored and analyzed to indicate the need for maintenance program amend-ment. This process, entitled "condition monitoring", was first recognized in the decision logic of the initial maintenance steer-ing group document MSG-1 and was applied to Boeing 747 aircraft.

(d) The experience gained with MSG-1 was used to update its decision logic and create a more universal document for application to other aircraft or powerplants. This document was designated MSG-2. When applied to a particular aircraft type, the MSG-2 logic results in a list of "mainte-nance significant items" (MSI's), to each of which is assigned one or more of the three process categories described above.

(e) After more than a decade of MSG-2 use, experience indicated that a further update was appropriate. As a result, a new industry task force developed MSG-3, which uses the basic philosophies of MSG-1 and MSG-2, but prescribes a different approach in the assignment of maintenance requirements. In lieu of process categories, MSG-3 identifies mainte-nance tasks. The development of this task orien-ted decision logic came about, partly in response to the misunder-standing which had been expe-r-ienced with the terms on-condition and condition monitoring, and partly due to the realization that the reliability monitoring (on a unit basis) of items having only benign failure modes was an economic, rather than a safety re-quirement. Detailed explanations of the MSG-2 and MSG-3 analysis methods may be found in AMA 571.101/3 (Maintenance review boards).

Although primarily intended for the initial development of inspec-tion programs for new aircraft, these methods may also be used, in conjunc-tion with service experience, to modify the programs of earlier air-craft.

(f) The processes, tasks and intervals arrived at by the use of MSG-1, -2 or -3, or, in the case of earlier aircraft, by the manufac-turers' sub-jective analyses, are used by the operator as the basis of his initial maintenance program. Subsequent amendments to that program must be consistent with the initial logic used, and will be based upon the operators experience with the aircraft type. The means by which that experience is analyzed, quantified, and used to indicate required changes, are collectively known as the operator's "relia-bility pro-gram". Over a period of time the changes implemented as a result of a reliability program can be significant. An example of how the "B" check intervals of a first generation jet aircraft have grown by the use of reliability moni-toring may be found on page 19.

5. RELIABILITY PROGRAM FORMAT

(a) An air carrier reliability program should be tailored to meet the special requirements of the particular operator, and should take into account his operational and environmental circumstances, organizational structure, record keeping system, etc. The scope of each operator's reliability program will be defined in his mainten-ance control manual. All or part of an operator's mainte-nance program may be controlled by use of reliability methods, and a typical program may include segments devoted to systems, compo-nents, powerplants and structures. All segments of the pro-gram may use identical methods, or each may be handled individu-al-ly. A reli-ability program may encompass a select group of items without affecting other controls for the remain-ing items.

(b) Statistical type programs may be used wherever the frequency of events being monitored is sufficient. This type of program enables the use of alert rates which may be shown on graphic charts (or equiva-lent displays) to identify areas where corrective action may be needed. Where the frequency of events is too low to provide valid statistical data, sampling inspection and defect analysis may be used to assess the relationship between operating time and the failure resis-tance of components. These types of programs are respectively known as "alert" and "non-alert" pro-grams. In practice most reliability programs include elements of both techniques. The description of a program as an "alert" or "non-alert" type generally indicates the predominant method used.

6. PROCESS CATEGORIES AND TASKS

(a) The basis of each operator's inspection program is a list of items, together with the processes or tasks assigned to those items, and the intervals at which action is required. The primary categories of main-tenance pro-cess for MSG-2 based programs are hard-time, on-condition and condition monitoring. MSG-3 tasks are categorized as inspections, functional checks, operational checks, servic-ing/lubrication, restora-tion, dis-card, operating crew moni-toring and "no scheduled" tasks. Each inspec-tion program should include specific definitions of the process cate-gories and/or tasks it uses, and how they are applied.

(b) There is no hierarchy of processes or tasks, and complex (multi-cell) units may be subject to control by one or more of them. It should be noted, however, that some tasks may be included to meet a safety re-quirement, while others may have a primarily economic purpose. Before amending the inspection program, it may be neces-sary to refer to the initial analysis to determine which of these purposes applies. If not known to the operator, this information can be obtained from the manu-facturer.

7. RELIABILITY PROGRAM ELEMENTS

Both alert and non-alert type programs will usually include the follow-ing elements: (a) data collec-tion, (b) analysis, (c) display and re-porting, (d) responsive action, and (e) program amendment procedures. The intent of the following paragraphs is not to provide rigid specifi-cations, but rather to explain the purpose of each of these elements which the operator may incorporate in his particular program.

(a) Data collection. The data collection system should provide a specific flow of information from identified sources, and proce-dures for trans-mission of data, including the use of forms, com-puter print-outs, etc. Responsibilities within the operator's organiz-ation must be established for each source of data collec-tion. Typical sources of performance information are described below; however, it is not implied that all of these sources need be included in the program, nor does this listing prohibit the use of others.

(1) Pilot reports

Pilot reports, more usually known as "Pireps", are reports of occurrences and malfunctions entered in the aircraft journey log by the flight crew. Pireps are among the most signifi-cant sources of information, since they are a direct indica-tion of aircraft reliability as experienced by the crew. It is usual for the journey log entries to be routed to the reliability section at the end of each day, or at some other agreed

interval, whereupon each entry is extracted and recorded as a count against the appropriate system. Engine performance (trend) monitoring can also be covered by the Pirep system, and may be used as a source of data in the same way as reports on system malfunctions, however it should be kept in mind that this form of monitoring is primarily inten-ded as a part of the "on-condition" process.

(2) Mechanical interruptions/delays

Aircraft delays and cancellations resulting from mechanical defects are normally reported daily by the operator's line maintenance staff. Each report gives the cause of delay and clearly identifies the system or component in which the defect occurred. The details of any corrective action taken and the severity (period) of the delay are also included. The delays are usually listed in Air Transport Association of America Specification 100 (ATA 100) chapter sequence.

(3) Engine in flight shutdowns

Flight crew reports of engine shutdowns usually include details of the indications and symptoms prior to shutdown. When ana-lyzed, these reports provide an overall measure of propulsion system reliability, particularly when coupled with the results of the subsequent investigations and with the records of unscheduled engine removals.

(4) Unscheduled removals

Component unscheduled removals are reported, together with the following information:

(i) Identification of component;

(ii) Precise reason for removal;

(iii) Aircraft registration and component location;

(iv) Date and airframe hours at removal; and

(v) Component hours since new/repair/overhaul/calibration.

(5) Confirmed failures

With the exception of self-evident cases, each unscheduled removal report is followed up by a workshop report in which the reported defect is confirmed or denied. This report is routed to the reliability section. Workshop reports may be compiled from an operator's own "in-house" findings and/or from details sup-plied by component repair/overhaul contrac-tors.

Where a reported malfunction is confirmed, the workshop report will normally include details of the cause of the defect, the corrective action taken and, where relevant, a list of replace-ment items. Many programs utilize the same type of report to highlight structural and general aircraft defects found during routine maintenance checks.

(6) Miscellaneous reports

Dependent upon the formation of individual programs, a va-riety of additional reports may be produced on a routine or ad hoc basis. Such reports could range from formal minutes of reliability meet-ings to reports on the sample stripping of components, and also include special reports which have been requested during the investigation of any item which has been highlighted by the pro-gram, such as service difficulty re-ports.

(b) <u>Data analysis</u>

Data analysis is the process of evaluating mechanical performance data to identify characteristics which indicate a need for program adjust-ment, revision of maintenance practices or hardware improve-ment (modi-fication). The initial step in analysis is the compari-son of the data to a predetermined standard of performance. This comparison may involve statistical calculations (alert type pro-grams) or other methods (non-alert type programs).

With both alert and non-alert type programs, the objectives of data analysis are to verify acceptable levels of perfor-mance, to identify trends which may need corrective action, and to indicate those tasks and intervals which may be safely eliminated, modi-fied or extended.

(1) Alert type programs

Programs incorporating statistical performance standards use parameters such as delays, Pireps per 1,000 departures or com-ponent removals/failures per 1,000 hours, for each air-craft sys-tem, or total delays/cancellations per 100 depar-tures for the entire aircraft. The choice of units of mea-surement is not critical provided that they are constant throughout the opera-tion of the program and are appropriate to the type and frequency of the events being recorded.

When prepared as a running graphical or tabular display of cur-rent performance, these data depict trends as well as show out--of-limits conditions. The system performance data is usually reinforced by reports of component removals or con-firmed fail-ures.

The data are then compared with a reliability alert level (or equivalent title, e.g. performance standard, control level, reli-ability index, upper limit, hereinafter referred to as an "alert level") which, when exceeded, indicates that there has been an apparent deterioration in the normal behaviour pattern of the system or component with which it is associa-ted. When an alert level is exceeded, appropriate corrective action must be taken. It should be recognized that alert levels are not minimum accept-able airworthiness levels. Rather, they are a means of ident-ify-ing those increases in failure rate which fall outside the bounds of normal distri-bution and therefore warrant further investiga-tion.

Alert levels can range from zero (for critical components, and for those where failures in service have been extremely rare) to perhaps as many as 100 Pireps per 1,000 hours on a systems basis, for less critical systems, such as ATA 25 (equipment/ furnishings). Wherever possible, they should be based on the number of events which have occurred during a representative period of safe operation of the aircraft fleet. Alert levels should be revised periodically to reflect operating experi-ence.

When establishing alert levels based on operating experience, the normal period of operation taken is between two and three years, dependent upon fleet size and utilization. The levels will usually be so calculated as to be appropriate to the numbers of events recorded in one-month or three-month periods of operation. Large fleets will generate sufficient signifi-cant information much sooner than small fleets. Some examples of alert level calculations may be found in Appendix "A".

Where there is insufficient operating experience, or when a program for a new aircraft type is being established, the following approaches may be used.

(i) For a new aircraft type during the first two years of operation all malfunctions may be considered signifi-cant (i.e. alert level zero) while data is accumulat-ed for future use.

(ii) Alternatively, levels may be established based on the degree of system and component in-service reliability assumed in the design of the aircraft. These estima-t-ed values are normally quoted in terms of mean time between unscheduled removals (MTBUR) or mean time between failures (MTBF) for both individual components and complete systems. These initial predictions should be replaced by actual reliabil-ity figures when sufficient in-service experience has been accumulated.

(iii) For an established aircraft type with a new operator, the alert levels of other operators may be utilized until the new operator has accumulated suf-ficient ex-perience. Alternatively, experience gained from oper-ation of a similar aircraft model may be used.

Both the method used for establishing an alert level, and the associated qualifying period, apply also when the level is recalculated to reflect current operating experience. However, if during the period between recalculations of an alert level, a significant change in the reliability of an item is experienced, which can be related to some known action(e.g. modification, change in maintenance or operating procedure) then the alert level applicable to the item should be reassess-ed, based upon the data subsequent to the change. The procedures, periods and conditions for recalculation of alert levels must be defined in the program docu-ment and approved by DOT.

(2) Non-alert type programs

Programs that do not depend upon statistics for their opera-tion (non-alert type programs) may be used by any size of organization and applied to any size of fleet. If the pro-grams are to be as effective as the statistically based pro-grams however, the number and range of inputs must be equiva-lent to those of the statisti-cal programs, and the operator's organization must have the ca-pability of analyzing the data to arrive at meaningful conclu-sions. This may involve the establishment of a dedicated section for the purpose. Less comprehensive non-alert type programs, which are applied to a limited number of components at any given time, may be handled by existing organizational elements, or even by a single indivi-dual.

Much of the information that is compiled to assist in the day to day operation of the operator's maintenance program may be effec-tively used as a basis for this type of continuous me-chanical performance analysis. Mechanical interruption sum-maries, flight log reviews, powerplant monitoring reports, incident reports, and powerplant and component analysis re-ports are examples of the types of information suitable for this monitoring method. Non--alert type programs also include many elements of maintenance management which are often not considered under the heading of "reliability". Examples in-clude trial programs for different (though previously ap-proved) lubricants, the documented use of different suppliers or overhaulers, and sampling (time trial) programs, whereby the escalation of times between overhaul of engines or other

components is based upon satisfactory strip reports following successive trial extensions.

(3) Changes in inspection program basis

Both types of program must include provision for the analysis of changes in the basis of the inspection program. Such changes may take the form of maintenance review board (MRB) report amendments, or changes in the maintenance planning document, or other manufacturers' recommenda-tions, transmit-ted by manual amendments, service bulletins or other means. Each change must be evaluated to assess its applicability to the operator's program.

(c) Data display and reporting

All programs will require some means of displaying and reporting the collected data, and should include a periodic reporting system with appropriate data displays, summarizing the activity of the previous period. The reports should cover all aircraft systems controlled by the pro-gram, in sufficient depth to enable DOT and other recipients to evalu-ate the effectiveness of the affected segments of the maintenance pro-gram. The reports should highlight systems which have fallen short of the established performance standards and discuss any action which has been taken, or is planned, including changes in maintenance and inspection intervals and changes from one process category and/or task to another. Continuing over-alert conditions carried forward from previous reports should be listed, together with details of the progress of any correc-tive action taken. Some examples of the types of data display used in reliabil-ity programs may be found in appendix "B".

(d) Responsive action

The actions to be taken in response to the data analysis should be positive enough to achieve the desired level of performance within a reasonable time. The system must include procedures to ensure DOT approval for any proposed changes in the inspection program, and for notification of the organizational element(s) responsible for taking the action. The system should also provide periodic feedback until such time as perfor-mance has reached an acceptable level. The procedures of the respon-sive action system may include work forms, special inspection procedures, engineering orders, etc. Special provision should be made for the control of critical items, the failure of which could impair the airworthiness of the aircraft.

Action taken in response to the findings of the reliability pro-gram can include changes in operational procedures or fault find-ing techniques, changes in fuels or lubricants, variation of stor-age conditions, the use of different sources of supply and the im-provement of training standards, etc. The major advantage of reliability control programs however, is that they afford the operator a formal means of substantiating applications for ap-proval to amend his existing maintenance schedules. The program document should include a description of the process by which such applica-tions will be made. The volume of data required to sub-stantiate the extension of a mainte-n-ance interval, or the change or deletion of a maintenance task, will depend both on the fre-quency of the task, and on the reason for its inclusion in the initial program. The minimum level of experience would normally be approximately one year, or one complete interval between the events in question, which-ever is the greater. Thus, high frequen-cy events, such as "A" check items, will require a relatively high volume of data, in the order of 25-50 events or more, while infrequent events, such as "D" check items, will usually require the operator to demonstrate satisfactory completion of at least one complete interval between the tasks under review. Similarly, changes to tasks introduced for safety reasons (e.g. in response to questions c or d of MSG-2, or questions 5 or 8 of MSG-3) will require significantly more substantiating data than those included primarily for economic or operational efficiency reasons. It will be necessary to refer to the original MRB report to determine the reason for each task.

Changes which involve the deletion of a task, or a change in the primary maintenance process (e.g. from on condition to hard time, or vice versa) must be subjected to the same analysis that was used to establish the initial program basis. This is sometimes referred to as the internal MRB procedure.

Changes to tasks designated as "airworthiness limitations", life limits, etc., may NOT be made on the basis of an operator's reli-ability program.

(e) Reliability program amendment. The program should include a des-cription of the procedures for its own revision. The description should identify the organizational elements involved in the revi-sion process and their authority. DOT approval will be required for any revision affecting:

(1) Data collection systems;

(2) Data analysis methods;

(3) Performance standards;

(4) Addition or deletion of aircraft types; and

(5) Procedural and organizational changes concerning the admin-istra-tion of the program.

8. ADMINISTRATION OF PROGRAMS

Participants in the reliability program should be drawn from ap-propriate elements of the organization and should be authorized to act on behalf of those elements. The principal airworthiness in-spector (PAI) assigned to the carrier, or any other DOT represen-tative, may participate in the administration of the program as an observer, but such participation will have no bearing on the ap-proval or rejection of any changes proposed.

(b) The makeup of the administration group may vary considerably from one operator to another. It may consist of a technical board that analyzes performance trends and shop findings to make recom-menda-tions. This board type of administration should have meet-ings scheduled at some specified interval, and should provide for the ad hoc assembly of the board at any time a decision is needed. An organization and data flow chart for this type of system is shown on page 16.

(c) Alternatively, operators with sufficient organizational capability may administer their program by assigning appropriate respon-sibili-ties to each organizational element. With this type of arrange-ment, responsibility for operation of the program should be as-signed to a specific element of the operator's organization.

(d) The procedures used for controlling each of the elements of the reliability program should be incorporated in appropriate sections of the operator's maintenance control manual. This will provide each organ-izational element, and individuals therein, with in-structions regarding their part in the program. Pre printed forms should be used to document recurring actions that involve several organiza-tional elements, such as the analysis of substandard sys-tems or components, shop analysis of components for purposes of task interval adjustment, and reports relating to aircraft check con-tent amendment.

9. Program document

(a) Reference is made in this advisory to a reliability program docu-ment. In practice this document will most likely take the form of a section of the operator's maintenance control manual, and should include at least the following:

(1) General description of the program;

(2) Organizational structure, duties and responsibilities;

(3) Description of the individual systems;

(4) Derivation of performance standards;

(5) Method of controlling changes to the program;

(6) Copy and explanation of all forms peculiar to the system; and

(7) Revision control system.

(b) The document should describe the workings of all systems in suf-ficient detail to provide for proper operation of the program. It should describe any reports relative to the program, and include samples of any forms used with instructions for their use. The organizational element(s) responsible for publishing reports should be identified and the distribution should be stated.

(c) The document should also include definitions of significant terms used in the program, with particular emphasis on definition of the process categories and/or tasks.

10. Program approval

Private operators may implement a reliability program without prior DOT approval. The program will, however, be subject to review prior to the approval of any inspection program changes which may be based upon it. Air carriers' reliability programs will be reviewed, and where appro-pri-ate, approved by DOT, as a part of the operators overall maintenance program. Approval of revisions to an air carrier's program will be by approval of the associated maintenance control manual amend-ment.

11. Joint Reliability Programs

A fleet size of 5 or more aircraft is usually considered necessary to generate sufficient data for the operation of an effective statistical-ly based reliability program. To accommodate the needs of smaller operators, participation in joint programs may be approved. Such pro-grams fall into two main categories, those primarily intended for the use of another operator, and those managed by a third party (usually either the aircraft manufacturer, or a supplier of computer services). Each of these types of program differs significantly from the other, as shown below.

(a) Operators' programs

Participation in the reliability program of another operator will re-quire the approval of the PAI, or equivalent airworthiness au-thority representative, of each operator. The applicants will be required to demonstrate sufficient commonality of aircraft config-uration, operating environment, utilization and route structure, to maintain the integrity of the program.

Responsibility for program management for each of the participat-ing fleets must be clearly defined, and the integration of data must be arranged so as to enable termination of the joint program without loss of applicable data. Data collection and analysis systems must include provision to detect significant differences in the participating fleets.

(b) Third party programs

This type of reliability program is most applicable to those air-craft types, such as business jets, where there may be no single large fleet operator. They may be regarded as data collection and analysis ser-vices, rather than complete programs. Multi partici-pant programs of this type are of most value in the pro-vision of operating data to the Maintenance Review Board to enable revision of the MRB report.

Nevertheless, such programs may meet the CM require-ments of MSG-2, and may be used by individual operators to demonstrate significant differences between their own and the global fleet, in support of changes to their own inspection pro-grams.

Third party programs are not approved as such. Instead, each indivi-dual operator must apply to DOT for approval for his parti-cipation in the program. This is usually considered part of the approval of the operator's inspection program.

12. Maintenance development programs

(a) Certain large air carriers may be authorized by DOT to make specified types of changes in their maintenance programs without prior approval. This privilege, previously known as a "continu-ous maintenance system" is granted by the issuance of a "mainte-nance development pro-gram" (MDP) approval. To qualify for such an approval, an air carrier must:

(1) Operate a large fleet of complex modern transport category air-craft, at a rate of utilization sufficiently high to permit the accumulation of experience at a rate commen-surate with that of the global fleet leaders;

(2) Have an established engineering department, operating as part of a reliability program which meets the general requirements of this advisory;

(3) Demonstrate, over a number of years, the effective manage-ment of their maintenance program, with particular emphasis on the sound-ness of any inspection program changes pro-posed; and

(4) Demonstrate that their reliability program is sufficiently active, in terms of the number and complexity of changes in-volved, to warrant the delegation of the approval respon-sibility to the carrier.

(b) The nature and scope of the approval privileges will be outlined in the air carrier's maintenance control manual. The approval may cover the entire maintenance program, or be restricted to certain specified areas of scheduled maintenance, dependent on the nature of the reliability monitoring techniques used, the carrier's organiz-ation, and the quali-fications and experience of the person-nel.

Maintenance development approval will NOT include the privilege of changing component life limits, or any requirements specified in air-worthiness directives, airworthiness limitations or MRB sampl-ing programs.

A chart depicting a typical maintenance development organization and data flow sequence is illustrated on page 17, adjacent to that for a typical reliability program, to facilitate comparison.

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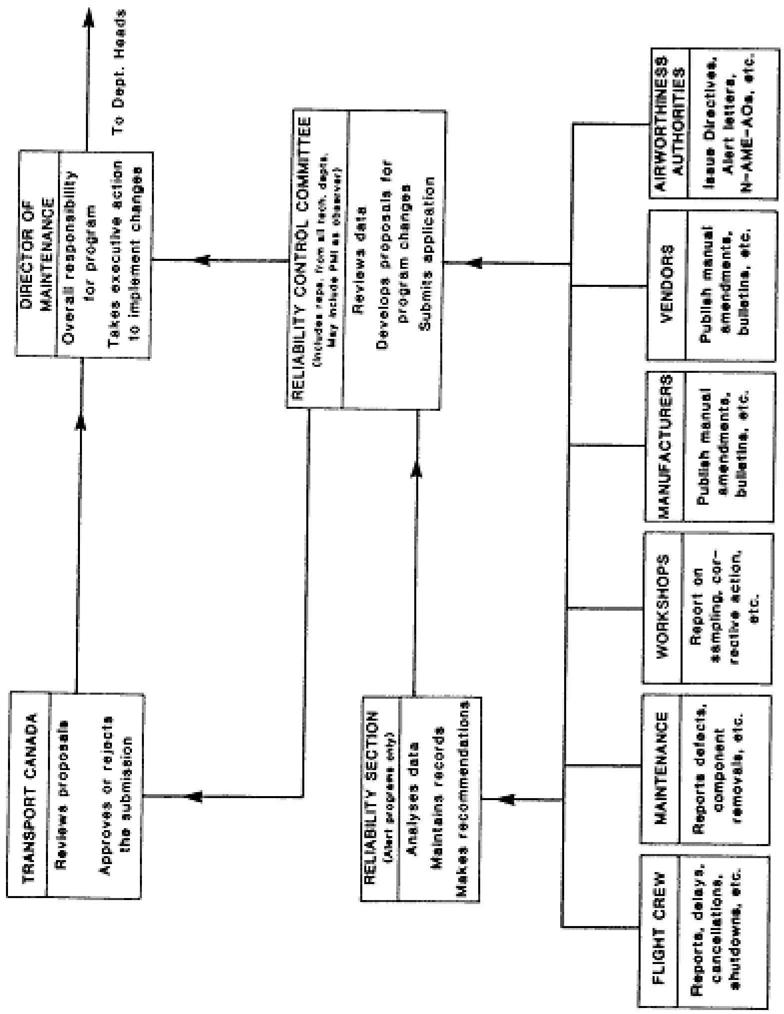
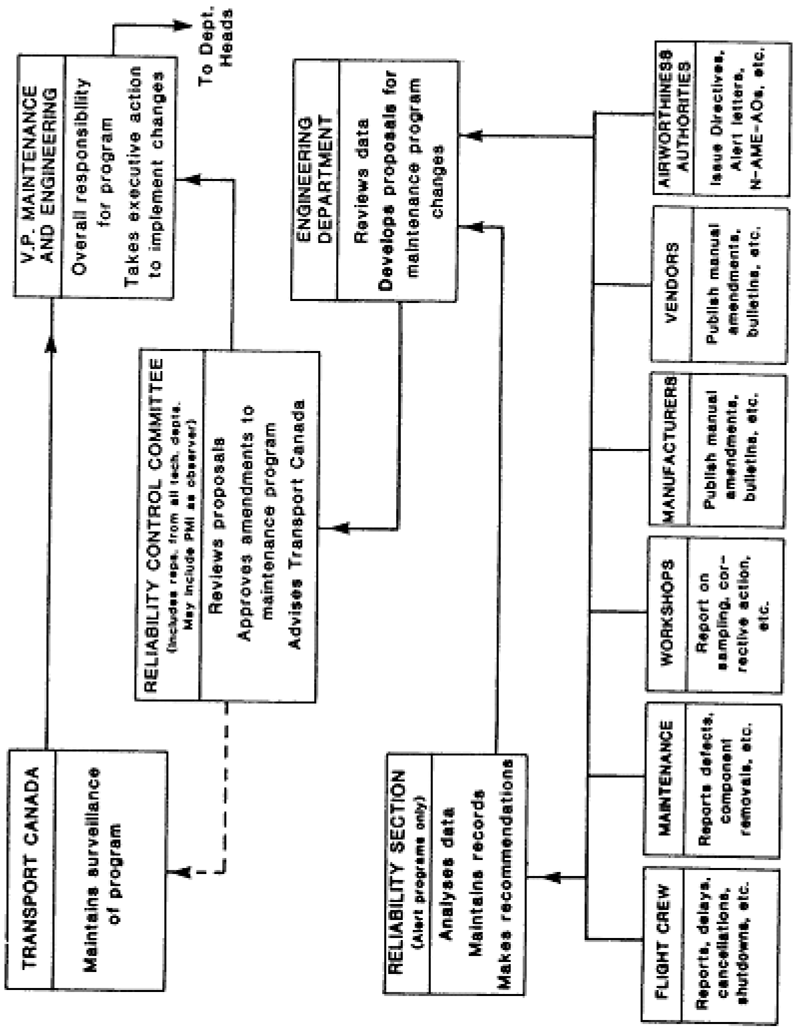
12. (a) Reliability program flow chart



12. (b) Maintenance development program flow chart



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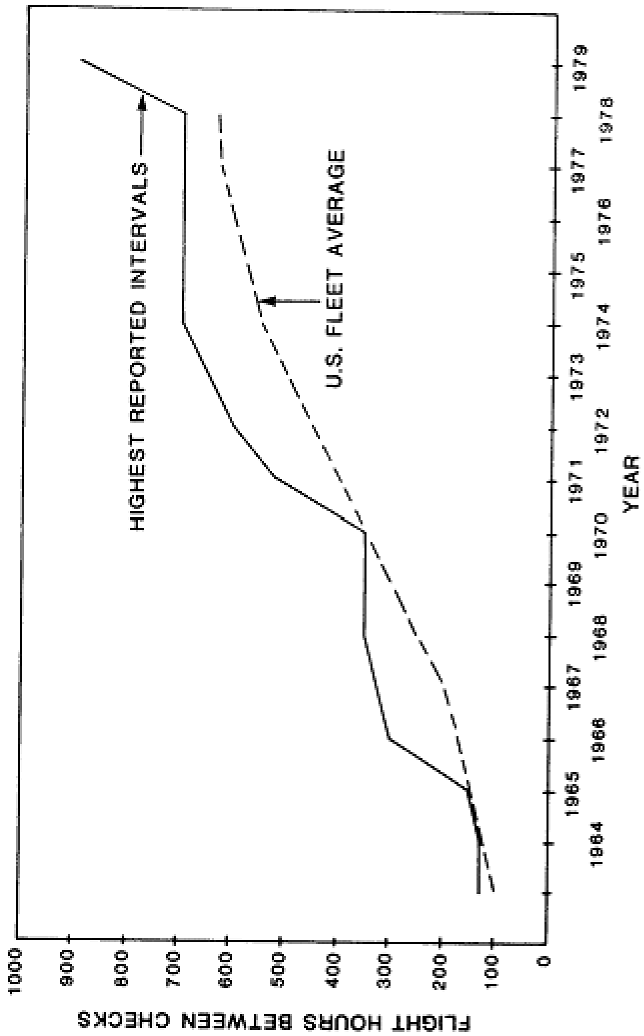

12. (c) B707 "B" check interval growth

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GLOSSARY OF TERMS

AIRWORTHINESS LIMITATIONS

Maintenance items, compliance with which is mandatory to maintain conformity with the type approval basis for a given type of aircraft.

CONDITION MONITORING (CM)

A maintenance process under which data on the whole population of specified items in service is analyzed to indicate whether some allocation of tech-nical resources is required. Not a preventive maintenance process, condi-tion monitored maintenance allows failures to occur, and relies upon analy-sis of operating experience information to indicate the need for appropriate action.

CONFIRMED FAILURE

When shop findings confirm a defect or failure which substantiates the reason for removal.

HARD TIME (HT)

A maintenance process under which a part is removed from service or over-hauled at fixed intervals defined in operating hours, operating cycles, or calendar time.

INSPECTION PROGRAM

A program for the scheduled maintenance of aircraft of a given fleet, devel-oped by the operator, and approved by DOT.

INTERVAL

The period (in flying hours, operating cycles or calendar time) which is permitted to elapse before a particular maintenance task is required, or between repeats of task.

LIFE LIMITED PARTS

Those items which, as a condition of the type approval, must be removed and discarded after specified time in service.

MAINTENANCE PLANNING DOCUMENT

A manufacturers recommendation on the maintenance of his product, produced in advance of, or concurrent with, the MRB report, and usually based on the same analyses which are submitted to the program development group, to enable prospective operators to establish maintenance schedules prior to the introduc-tion of a new type into service.

MAINTENANCE PROCESS

Classification of the manner in which a particular item is maintained.

MAINTENANCE REVIEW BOARD (MRB)

The section of an airworthiness authority responsible for the approval of recommendations made by industry on the maintenance requirements of new aircraft types.

MINIMUM EQUIPMENT LIST (MEL)

An approved list of items which may be inoperative for flight under speci-fied conditions.

MRB REPORT

The recommendations of a program development group, which are submitted to the airworthiness authority's MRB for approval, and thereafter form an ap-proved basis on which a new operator may establish his maintenance schedule.

MSG-1/2/3

Logic systems, developed by the maintenance steering group of the Air Trans-port Association of America, for use by program development groups in the analysis of an aircraft's maintenance requirements.

MTBF -MEAN TIME BETWEEN FAILURES

A performance figure calculated by dividing the total unit flying hours accrued in a period by the number of unit failures in that period.

$$\text{MTBF} = \frac{\text{Total unit hours this period}}{\text{Number of units failed this period}}$$

NOTE: MTBF does not account for unit hours flown in other periods, sched-uled unit removals, or units still operating.

MTBR -MEAN TIME BETWEEN REMOVALS

A performance figure calculated by dividing the total unit flying hours accrued in a period by the total unit removals (both scheduled and unsched-uled) in that period.

$$\text{MTBR} = \frac{\text{Total unit hours this period}}{\text{Number of units removed this period}}$$

NOTE: MTBR does not account for unit hours flown in other periods nor for units still operating.

MTTF -MEAN TIME TO FAILURE

A performance figure calculated by computing the average of the cumulative operating hours for each unit at failure.

$$\text{MTTF} = \frac{\text{Total unit hours accrued by all failed units}}{\text{Total number of units failed}}$$

NOTE: MTTF accounts for the average life of failed units only. Scheduled removals are not included.

MTTR -MEAN TIME TO REMOVAL

A performance figure calculated by computing the average of the total unit operating hours at removal for both scheduled and unscheduled removals.

$$\text{MTTR} = \frac{\text{Total unit hours accrued by all removed units}}{\text{Total number of units removed}}$$

NOTE: MTTR is the most accurate performance figure for the average "life" realized for all components.

ON-CONDITION (OC)

A maintenance process having repetitive inspections or tests to determine the condition of units, systems or portions of structure.

OPERATIONAL RELIABILITY

The ability to perform the required functions within acceptable operational standards for the time period specified.

PRIMARY MAINTENANCE PROCESS

The process primarily depended upon to ensure that inherent design reliabil-ity is maintained.

SAMPLING PROGRAM

A program applied to major items of equipment which are expected to be sub-ject to progressive deterioration in service, and for which there is insuf-ficient service experience to determine appropriate tasks and intervals. The purpose of the program is to collect data which will enable the identi-fication of the appropriate tasks and intervals, and indicate the need for product improvements.

SHOP FINDINGS

Detailed information concerning a component following repair, overhaul, bench test or sampling inspection. Information usually includes: confirma-tion of failure, details of failure modes/causes, parts replaced, condition of item, action taken, item disposition and recommendations concerning TBO, preventive maintenance, etc.

TASK

An action or set of actions intended to restore an item to, or maintain it in, an airworthy condition, including inspection to determine if the item is airworthy.

M. Khouzam

Chief

Airworthiness Standards

Appendix A

CALCULATION OF ALERT LEVELS

The purpose of an alert level is to identify significant deviations from a previously acceptable standard of performance. The level should not be set so high that a major increase in the failure rate does not produce an alert, nor so low that the normal distribution of failures results in excessive alerts. The actual setting of the alert level therefore, will normally depend upon the distribution or "scatter" observed in the failure rates of the system under review.

There are several recognized methods of calculating alert levels, any one of which may be used provided that the method chosen is fully defined in the operator's program document. The methods described in the following pages are offered as examples, and many more may be found in any standard text book on statistics.

For purposes of comparison, the first three examples use identical data. It will be seen that the resultant alert levels differ according to the method used, but these small differences are not considered to be of significance. With an effective data display system (see appendix "B") an inappropriately set alert level should be readily apparent.

The symbols used in this appendix have the following conventional meanings:

x (x bar)	= the mean of a set of data,
N	= the number of data,
X	= the values of the data,
Σ (The Greek capital letter sigma)	= the total of a set of data,
σ (The Greek letter sigma)	= standard deviation,
λ (The Greek letter lambda)	= no of failures,
t (The Greek letter Tau)	= time, and

λt (Lambda tau) = failure rate

Appendix A

EXAMPLE 1

Pireps -1.3 Mean Alert Level

The three month running average Pirep rate per 1,000 hours for each system (or sub-system), as in the table of figure 1 opposite, is averaged over the sample operating period and is known as the mean (x); the mean is multiplied by 1.3 to produce the alert level for the given system.

Although experience has shown this method to be effective with typical fail-ure patterns, it would produce excessive alerts when applied to a system with widely dispersed failure rates, and would not be sufficiently sensitive when applied to data with narrow dispersion.

In the example shown, the alert level (in this case, 26) would be exceeded in the months of July and August.

Appendix A

Figure 1

Pireps per 1,000 hrs

ATA 29 -Hydraulics

Pireps per 1,000 hrs

ATA 29 – Hydraulics

Month	Pireps (for month)	Pireps (3 month moving total)	Air Time (for month)	Air Time (3 month moving total)	Pirep Rate (per 1,000 hr) (for month)	Pirep Rate (per 1,000 hr) (3 month moving average) (X)
APR	34	-	2610	-	13	-
MAY	45	-	2730	-	17	-
JUN	66	145	3150	8490	21	17
JUL	79	190	2930	8810	27	22
AUG	75	220	2750	8830	27	25
SEPT	59	213	3050	8730	19	24
OCT	55	189	2700	8500	20	22
NOV	36	150	2660	8410	14	18
DEC	47	138	2380	7740	20	18
JAN	59	142	2400	7440	25	19
FEB	46	152	2350	7130	20	21
MAR	59	164	2610	7360	23	22
APR	30	135	2650	7610	11	18
MAY	43	132	2800	8060	15	16
					Total (Σx)	242

Number of data in sample (N) = 12

Mean (x) = $\frac{\Sigma x}{N}$ $= \frac{242}{12}$ = 20 (rounded)

Alert Level = 1.3x N = 1.3 x 20 = **26**

Appendix A

EXAMPLE 2

Pireps -2σ alert level (using electronic calculator)

The three month running average Pirep rate per 1,000 hrs for the system (or sub system) is averaged over the sample operating period and is known as the mean (x) as in example

1. The standard devia-tion (the root mean square of the amount by which the data differ from the mean) is calculated as shown, multiplied by 2, and added to the mean to produce the alert level.

Although in the example shown opposite, the resulting alert level is the same as that of the 1.3 x method of example 1, this would not always be the case. A 2σ alert is unlike the previous technique in being more respon-sive to the nature of the data, and is particularly suitable for highly scattered data (i.e. data with a high standard deviation).

With a 2σ alert, the probability of a spurious alert (one resulting from the scatter of a normal distribution) is approximately 4.5%.

In the example shown, the alert level is obtained by using an electronic calcula-tor having a statistical function. Actual key symbols and sequence may differ according to the model of calculator used.

Appendix A

Step 1:

Select statistical mode: INV (2nd function) MODE (stat or "SD")

Step 2: Clear: INV SAC (clear stats)

Step 3: 17 M+ 22 M+ 25 M+ 24 M+ 22 M+ 18 M+

Enter data:

19 M+ 21 M+ 22 M+ 18 M+ 16 M+

Step 4: key display

Obtain results: **Number of data** (N) n 12

Total (Σx) Σx 242

Mean (x) x 20.16666667

Standard Deviation (σ) σn 2.763853995

<u>Step 5</u>:

Alert level = 2 x 2.763853995 + 20.16666667 = 25.69437466

rounded to **<u>26</u>**

Appendix A

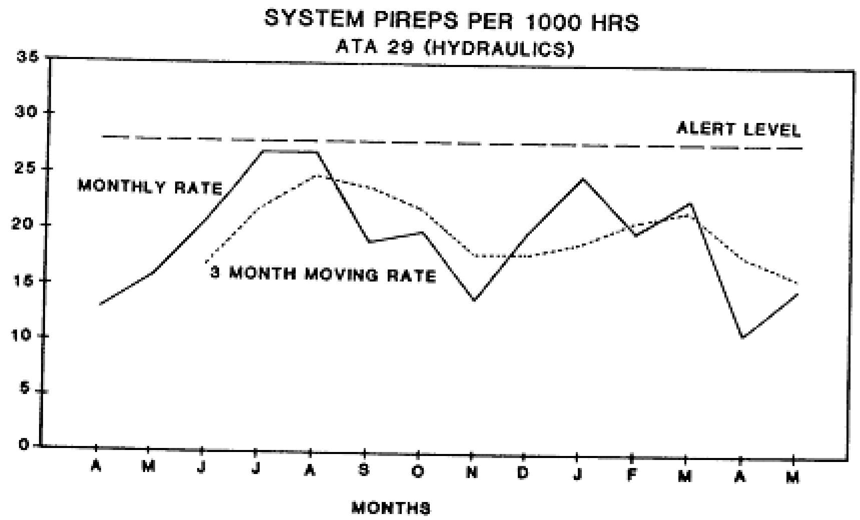
EXAMPLE 3

Pireps -3σ alert level

The mean, plus 3 standard deviations as shown in figure 3 opposite. 3σ is probably the most common alert level.

A 3σ alert is most suited to narrowly scattered data (i.e. data with a small standard deviation), the probability of a spurious alert with this method being 0.3%.

Unlike the previous methods, with the sample data shown, the 3σ alert level does not produce an alert for the months of July and August. A graphical presentation of the data used in the example is shown below.



Appendix A

Figure 3

Pireps per 1,000 hrs

ATA 29 -Hydraulics

Number of data in sample (N) = 12

Month	Pireps (for month)	Pireps (3 month moving total)	Air Time (for month)	Air Time (3 month moving total)	Pirep Rate (per 1,000 hr) (for month)	Pirep Rate (per 1,000 hr) (3 month moving average) (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
APR	34	–	2610	–	13	–	–	–
MAY	45	–	2730	–	17	–	–	–
JUN	66	145	3150	8490	21	17	–3	9
JUL	79	190	2930	8810	27	22	2	4
AUG	75	220	2750	8830	27	25	5	25
SEPT	59	213	3050	8730	19	24	4	16
OCT	55	189	2700	8500	20	22	2	4
NOV	36	150	2660	8410	14	18	–2	4
DEC	47	138	2380	7740	20	18	–2	4
JAN	59	142	2400	7440	25	19	–1	4
FEB	46	152	2350	7130	20	21	1	1
MAR	59	164	2610	7360	23	22	2	4
APR	30	135	2650	7610	11	18	–2	4
MAY	43	132	2800	8060	15	16	–4	16
					Total (Σx)	242	–	92

Mean (x) = $\frac{\Sigma x}{N}$

$= \frac{242}{12}$

= 20 (rounded)

Standard Deviation (σ) = $\frac{\Sigma (x-x)^2}{N}$

$= \frac{92}{12}$

= 7.67

= 2.77

Alert Level = Mean (x) + 3σ

= 20 + (3 x 2.77)

= 28.31 rounded to 28

Appendix A

EXAMPLE 4

Component unscheduled removals -Poisson method

The monitoring of individual components requires either a larger population or a greater experience level than the monitoring of complete systems. The following example is based on 21 months experience, and provides an alert level for use as a 3 month period of comparison. With a large population (either a large number of aircraft or a large number of components per air-craft) the time periods for both experience and comparison could be reduced. The alert level is set at 95% cumulative probability by reference to the chart of Poisson cumulative probabilities on the facing page, as shown in the following two examples:

(a) Component: Autopilot Pitch Amplifier

Number of components per aircraft n = **1**

Number of unscheduled removals in past 21 months N = **62**

Fleet utilization in past 21 months H = **36840**

Component running hours in past 21 months T = **(n x H) = 36840**

Fleet utilization in current 3 months h = **5895**

Component running hours in current 3 months t = **(n x h) = 5895**

Number of unscheduled removals in current 3 months x = **12**

Mean unscheduled removal rate, $= \frac{N}{T} = 0.00168$

Expected unscheduled removals in current 3 months, **= 0.0168 x 5895**

= 9.9 rounded to 10 (

Referring to Fig. 4, by entering the graph at t = 10 the intersection with 0.95 (95% probability) gives the maximum acceptable number of unscheduled component removals (A value) for the 3 month period as **15.**

By comparing the current value of x = 12 one can see that an "alert" situation does not exist for this component

(b) Component: Temperature Control Valve

Number of components per aircraft n = **3**

Number of unscheduled removals in past 21 months N = **31**

Fleet utilization in past 21 months H = **36840**

Component running hours in past 21 months T = **(n x H) = 110520**

Fleet utilization in current 3 months t = **(n x h) = 17685**

Component running hours in current 3 months h = **5895**

Number of unscheduled removals in current 3 months x = **9**

Mean unscheduled removal rate, $= \dfrac{\mathbf{31}}{\mathbf{110520}}$ **= 0.00028,**

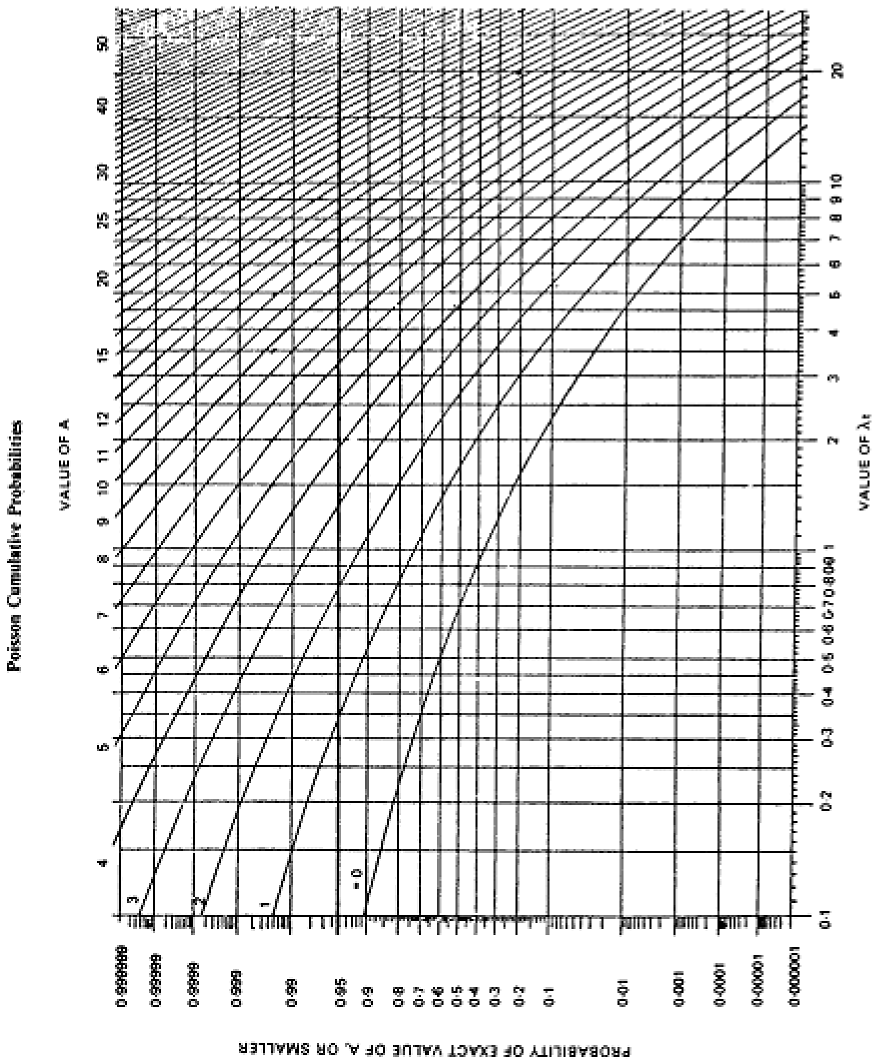
Expected number of unscheduled removals in current 3 months = **0.00028 x 17685**

= **5.01 rounded to 5 (**

From graph acceptable A value = **8**.

Current value of x = 9, therefore alert level <u>is exceeded</u> in this case.

Figure 4



Appendix A

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Appendix B

<u>TYPICAL DATA DISPLAYS AND REPORTS</u>

The main purpose of the displays shown in the following examples is to pro-vide the operator's management (including the reliability control committee, where appropriate) and DOT, with a readily understandable depiction of fleet reliability for the period under review.

Information may be presented in either graphical or tabular format, provided that the method adopted conveys the required information clearly. Tabular displays generally provide more precise information, while graphical dis-plays are preferable for indicating trends. It is usual to show current performance as it relates to past experience, and where appropriate the current alert level is shown for reference.

A well developed reliability program may be completely integrated with the carrier's overall maintenance management system, therefore displays may also incorporate data required for other economic or quality control functions, such as ratio of commercial to non-revenue flying, cost-benefit analyses for proposed modification action, identification of recurring defects, etc.

Appendix B

Example 1 -Fleet reliability summary

This display (fig. 1, opposite) applies to all aircraft of the same type in the fleet, is usually produced in tabular form, and should contain the fol-lowing minimum information for the defined reporting period:-

(A) Number of aircraft in fleet;

(B) Number of operating days (less checks);

(C) Total number of flying hours;

(D) Average daily utilization per aircraft;

(E) Average flight duration;

(F) Total number of landings; and

(G) Total number of delays/cancellations.

As shown in the example, it usually includes a summary of the previous period for comparison, and may also include information of purely commercial interest to the operator, such as the ratio of revenue to non-revenue flying, etc. The remarks section provides a means of identifying the causes of cancellations and other technical incidents, for future reference.

Appendix B

Figure 1

FLEET RELIABILITY SUMMARY

AIRCRAFT TYPE		PREVIOUS YEAR	CURRENT YEAR												ACCUM TOTALS
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
NUMBER IN FLEET		8	8	8	8	8	8	8							
OPERATING DAYS		2240	166	170	175	190	200	205							1106
FLYING HOURS	Revenue	19320	1400	1421	1610	1780	1702	1784							9697
	Non Revenue	50.7	8	6	6	15	14	8							57
	Training	115.3	-	35	25	47	2	5							114
	TOTAL	19486	1408	1462	1641	1842	1718	1797							9868
DAILY UTILIZATION		8.7	8.5	8.6	9.4	9.7	8.6	8.8							8.9
AVERAGE FLIGHT DURATION		2.5	2.6	2.7	2.6	2.8	2.7	2.6							2.7
MOVEMENTS	Revenue	7728	537	514	624	653	632	690							3650
	Non Revenue	66	4	12	7	5	8	3							39
	Training														
	TOTAL	7794	541	526	631	658	640	693							3689
DELAYS (more than 15 mins)	Number	150	5	7	14	16	8	7							57
	Total time	380:2	3:45	6:50	11:50	13:30	5:35	3:50							45:20
	% Delays	1.94	.93	1.36	2.24	2.46	1.27	1.01							1.56
CANCELLATIONS		5	-	-	1[1]	-	-	2[2,5]							3
TECHNICAL INCIDENTS	Interruptions	3	-	-	-	1[3]	-	-							1
	Shut Downs	2	-	-	-	-	1	-							1
	Other (see remarks)	-	1[4]	-	-	-	-	-							1
REMARKS		[1] -Fuel leak [2] -Skin repair (damage by forklift) [3] -Diverted due to smoke in cabin (cabin air compressor break-up) [4] -Tire burst (anti-skid failure) [5] -FOD													

Appendix B

__**Example 2 -Aircraft mechanical delays/cancellations**__

This type of display indicates the aircraft systems which have caused delays or cancellations as a result of mechanical malfunctions. It is normal to present a display of the total aircraft delays/cancellations as shown in figure 2a to indicate the occurrences due to all systems as a measure of fleet overall reliability. This is often supplemented by an analysis of each delay, showing the component(s) responsible, action taken and recom-mendations for future action to prevent a recurrence (fig. 2b). Some pro-grams present delay information by ATA system. The displays for the sepa-rate systems will usually show the delay/cancellation rate for the defined reporting period, and where appropriate the alert level, and will present the information for a 12 months period.

Figure 2a

TOTAL AIRCRAFT DELAYS/CANCELLATIONS												
BASE	NO. OF MOVEMENTS			NO. OF TECH. DELAYS			TOTAL DELAY TIME (hr:min)			(%) DELAYS		
	JAN	FEB	MAR	JAN	FEB	MAR	JAN	FEB	MAR	JAN	FEB	MAR
MONTREAL	184	168	170	10	6	5	8:50	6:20	10:00	5.4	3.6	2.9
TORONTO	44	46	17	1	3	0	0:45	3:25	-	2.3	6.5	-
VANCOUVER	127	70	94	3	1	2	5:50	6:00	3:50	2.4	1.4	2.1
TOTALS	355	284	281	14	10	7	15:25	15:45	13:50	3.94	3.52	2.49

Appendix B

Figure 2b

FLEET DELAY ANALYSIS						
DATE	**FLT No.**	**ACFT IDENT.**	**DELAY**	**REPORT Rcvd**	**ATA**	
						REASON FOR DELAY: Shortly before dep. FRA found girt bar door 5L off hooks and one girt bar shoe missing.

10	571	607	0:50	NO	52	 **RECTIFICATION:** New girt bar shoe installed and girt bar re-installed. **RECOMMENDATIONS:**
13	52	602	0:13	YES	35	**REASON FOR DELAY:** (40 min. late inbd) T/S repeated pax 0_z indication problem. Also noted #5 pax 0_z leaking. **RECTIFICATION:** Bottle replaced and leak check accomplished on all pax 0_z lines in fwd cargo compt. **RECOMMENDATION:**
14	451	611	2:10	YES	71	**REASON FOR DELAY:** #4 engine unscheduled change and repairing hyd leak on EDP pressure line engine # 1 (after engine change). **RECTIFICATION:** 2nd stage turbine blade failure due internal corrosion. **RECOMMENDATION:**
						REASON FOR DELAY: **RECTIFICATION:** **RECOMMENDATION:**
						REASON FOR DELAY: **RECTIFICATION:**

						RECOMMENDATION:

Appendix B

Example 3 -Engine unscheduled shutdowns and unscheduled removals

These data are the prime indicators of engine in-service reliability, and also, to a large degree, of total powerplant reliability. Because of the high level of reliability of engines, and the consequent relatively low num-bers of unscheduled shutdowns per fleet, both the actual number of shut-downs and the shutdown rate per 1,000 hours are shown. When dealing with small numbers of unscheduled shutdowns, it is usual to present both types of in-formation in such a way as to show the trend over a two to three year peri-od. Many operators show scheduled removals, unscheduled removals and in-flight shutdowns on the same display, as shown in figure 3.

Appendix B

Figure 3

UNSCHEDULED ENGINE REMOVALS AND SHUTDOWNS														
AIRCRAFT TYPE:	CURRENT YEAR												ACCUM TOTALS	PREVIOUS YEAR TOTALS
ENGINE TYPE:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
ENGINE HOURS	2735	2486	3306	4227	4572	5400							22726	45149
UNSCHED. REMOVALS	-	-	-	-	1	1							2	4
RATE PER 1000 HRS.	-	-	-	-	0:21	0:18							0.09	0.09
REASON:														
Failure	-	-	-	-	1	1							2	4
External causes	-	-	-	-	-	-							-	-
FINDINGS:														
Basic engine failure	-	-	-	-	-	1							1	2
Accessory failure	-	-	-	-	1	-							1	2
Unsubstantiated	-	-	-	-	-	-							-	-
ACTION:														
H.S.I.	-	-	-	-	-	-							-	-
Overhaul	-	-	-	-	-	1							1	2
Other	-	-	-	-	1	-							1	2
SCHED. REMOVALS:														
Total	2	2	1	1	-	-							6	7
H.S.I.	2	-	-	-	-	-							2	2
Overhaul	-	2	1	1	-	-							4	5
SHUTDOWNS:														
Total number	-	-	-	-	-	1							1	2
Rate per 1000 hrs.	-	-	-	-	-	-							0.04	0.04

Appendix B

Example 4 -Pireps

Pireps are presented by system or subsystem (normally identified in accor-d-ance with ATA 100) in graphical and/or tabular form as a rate per 1,000 flight hours or 100 departures, for comparison with the alert level (see fig. 4a). Some programs may include a presentation of fleet Pireps (see fig. 4b). This presentation shows the total number of Pireps for all systems and subsystems and thus gives an overall picture of the operator's total Pireps for the aircraft type.

Figure 4a

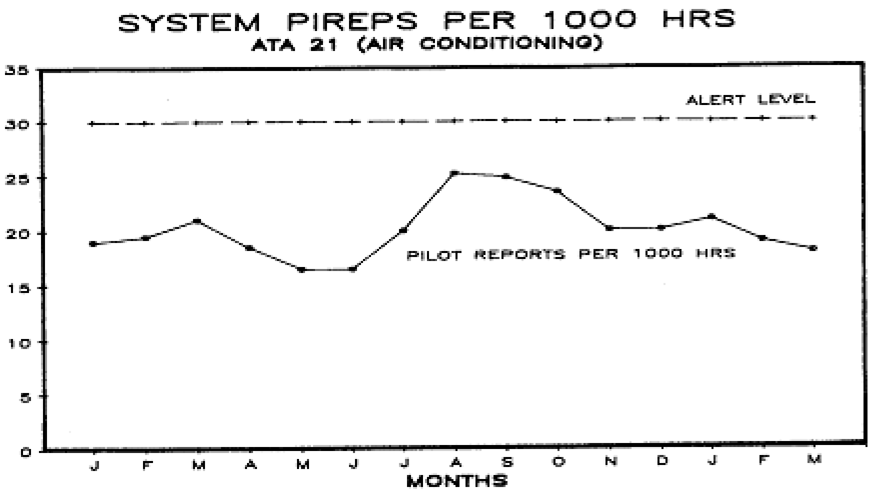
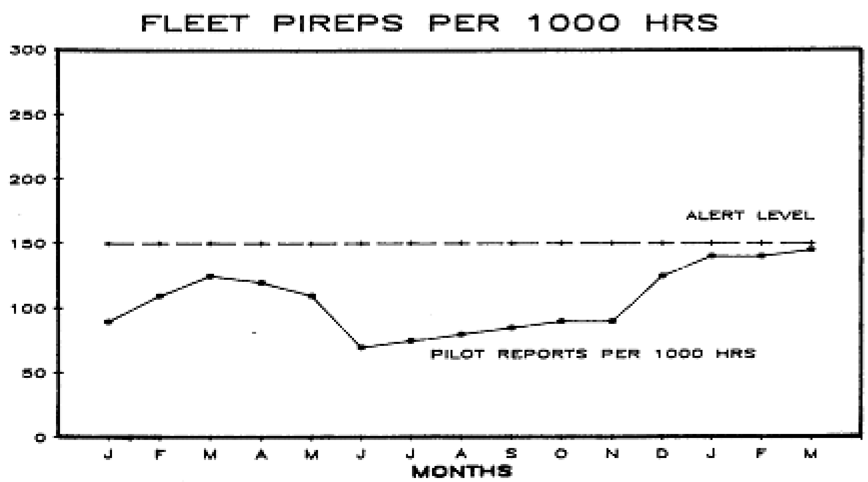


Figure 4b



Appendix B

Example 5 -Component unscheduled removals and confirmed failures

The format of any display of component information is normally such that current performance may be compared with both the alert rates and with the performance of the previous reporting period. The inclusion of information relating to the confirmation of the reported failures provides an additional check on the effectiveness of trouble shooting procedures.

There are various methods of displaying component information. The display may be on the basis of the total number of affected components per system and be presented graphically (see fig. 5a below) or in tabular form (see fig. 5b opposite). Alternatively, components may be addressed individually as shown in example 6, on the following page.

Figure 5a

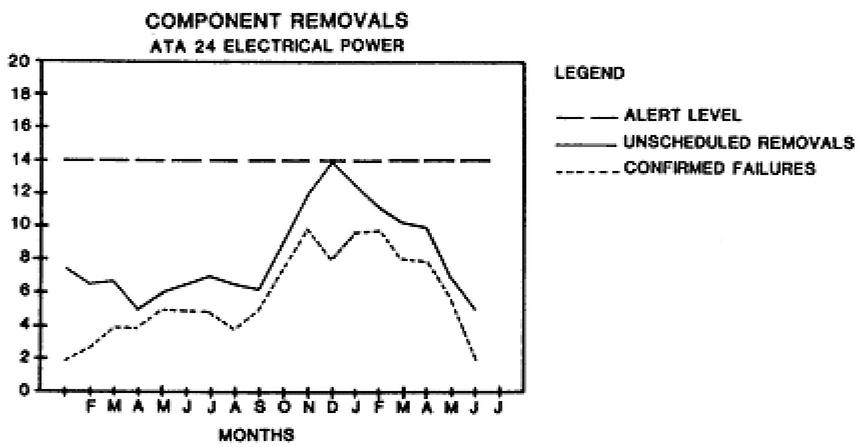


Figure 5b

Component Unscheduled Removals and Confirmed Failures

AIRCRAFT TYPE:		JANUARY 1971			1970 FIRST HALF			1970 LAST HALF		
ATA 100 CHAPTER	ALERT LEVEL	UR*	URR†	FR‡	UR*	URR†	FR‡	UR*	URR†	FR‡
21 — Air Conditioning	·35	2	·53	·33	14	·34	·32	15	·36	·31
22 — Auto-pilot	·80	4	1·33	·33	16	·98	·29	19	·98	·32
23 — Communications	·92	2	·67	·48	10	·57	·48	8	·56	·37
24 — Electric Power	·20	2	·08	·02	8	·06	·02	9	·07	·03
27 — Flight Controls	·30	1	·20	·09	7	·12	·10	6	·10	·08
28 — Fuel	·23	0	·00	·00	2	·64	<u>·30</u>	1	·09	·06
29 — Hydraulic	·38	1	·42	<u>·40</u>	2	·26	·18	4	·46	·22
30 — Ice & Rain Protection	·15	0	·00	·00	2	·14	·08	2	·14	·08
31 — Instruments	·65	4	·63	·34	20	·61	·31	16	·57	·20
32 — Landing Gear	·33	1	·04	·02	7	·05	·03	9	·09	·04
34 — Navigation	·73	3	·66	·21	20	·69	·24	24	·71	·29
35 — Oxygen	·30	2	·66	<u>·32</u>	11	·65	<u>31</u>	9	·64	·30
36 — Pneumatic	·20	0	·00	·00	2	·01	·01	4	·02	·02
38 — Water/Waste	·24	1	·09	·06	6	·16	·15	7	·17	·16
49 — APU	·48	1	·33	·32	7	·34	·34	4	·26	·29
73 — Engine Fuel & Control	·39	0	·00	·02	4	·10	·06	2	·06	·05
75 — Engine Air	·28	1	·17	·16	5	·16	·14	3	·12	·12
77 — Engine Indicating	·30	5	·42	·17	26	·46	·18	22	·44	·17
79 — Oil	·22	0	·00	·00	2	·04	·02	3	·06	·04
80 — Starting	·50	1	·17	·11	6	·18	·12	3	·09	·10

*UR — Unscheduled Removals
†URR — Unscheduled Removal Rate
‡FR — Confirmed Failure Rate (3 months cum. av.)

Example 6 -Unscheduled removals and confirmed failures

Experience has shown that a tabular presentation on an individual component basis is often the most useful means of displaying unscheduled removals and confirmed failures. The example shown in fig. 6 demonstrates this type of presentation. The preparation of such a display is time consuming, but it has the advantage of readily identifying troublesome components. Probably the most practical approach is the use of graphical system based displays for all systems, supplemented by a component based tabular display of the type shown opposite, for the most trouble-prone sys-tems.

Figure 6

COMPONENT UNSCHEDULED REMOVALS AND CONFIRMED FAILURES												
ATA 21 - Air Conditioning/Pressurization												
		FLYING HOURS	13408			2495				ACCUMULATIVE COMPONENT CONFIRMED FAILURES		
PART NUMBER	NO. PER A/C	COMPONENT / PERIOD	1985			1st Qtr. 1986			ALERT LEVEL	SINCE 1.1.74		
		DATA	A*	B*	C*	A*	B*	C*		A*	B*	MTBF
131046-1	1	Manual Pressure Controller	-	-	-	2	0.15	-	-	2	0.015	6600
102518-3-1	1	Auto Cabin Pressure Con-troller	4	0.30		-	-	-	0.39	19	0.068	14000
10-3280-5-1	2	Cabin Outflow Valve	5	0.19	2	1	0.04	1	0.25	9	0.072	13894
178040-2-1	4	Heat Exchanger	-	-		-	-	-	-	5	0.009	105600
204050-10-1	2	Air Cycle Machine	2	0.07		-	-	-	0.09	10	0.038	26400
129150-2-1	2	35° Thermostat Pack Anti-Icing	1	0.07		-	-	-	0.09	1	0.004	264000
321674-3-1	2	Valve-Pack Shut-off	1	0.04	2	-	-	-	0.05	5	0.019	52800
541248-2-1	2	Actuator-Ram Air	1	0.04		-	-	-	0.05	2	0.008	132000
207562-1	2	Fan Cooling Pack	2	0.07		-	-	-	0.09	8	0.030	33000
18801-5	1	Detector-Air Flow Sensor	-	-	-	-	-	-	-	1	0.008	132000
321402-1-1	2	Valve/Actuator-Control Mix	-	-	-	1	0.04	-	-	5	0.019	52800
548376-5	1	Controller-Air Temp.	1	0.07		-	-	-	0.09	2	0.015	66000
67321-10-190	3	Temperature Sensor	-	-	-	-	-	-	-	1	0.003	396000
163B1501	2	Indicator-Pack Temp.	-	-	-	-	-	-	-	1	0.004	264000
132322-2-1	1	Fan Venturi	2	0.15		1	0.07	-	0.20	4	0.030	33000
548392-1-1	2	Cabin Temp. Sensor	1	0.04		-	-	-	-	1	0.004	264000
32-2684-002	1	Cargo Outflow Valve	-	-		1	0.07	-	-	2	0.015	66000
500702-4620	2	Gasper Fan	-	-		-	-	-	-	4	0.015	66000

A* - No. of unscheduled removals B* - Failure Rate per 1,000 hours C* - Non-confirmed Defects

Example 7 -Workshop reports

Computer printouts are sometimes used to display the distribution of fail-ures of particular components as a function of time in service. The nature of the defects, as disclosed by shop findings, may also be displayed on the same report. An example of this type of display is shown in figure 7a.

In this example, the wide distribution of times between unscheduled remov-als, and the low mean time between failures (MTBF) of 5690 hrs indicate that the current hard time between overhauls (TBO) of 9000 hrs may be inappro-priate. The small percentage of units remaining in service for the full TBO (26%), and the fact that 22% of the unscheduled removals occurred within the first 900 hrs of operation would warrant further investigation.

A summary of the results of defect investigations, based on the workshop reports, is normally produced by component type, as shown in figure 7b, while a more comprehensive form, providing space for detailed comments on each component, is illustrated in figure 7c.

Figure 7a

COMPONENT REPORT # A/C 747B REPORT PERIOD 1 APR TO 1 OCT

ATA 24-11-D10 PART# CONSTANT SPEED DRIVE

SHOP-FINDINGS AND FAILURE DISTRIBUTION DATA

AGE (HRS X00)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	TOTL
SCHED REMOVALS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	8	1		14
UNSCH REMOVALS	4	3	1	2	1	-	2	1	1	3	2	1	2	1	3	2	2	1	-	-	32
OTHER REMVL*	1	-	-	-	1	1	-	-	1	-	-	1	-	-	-	1	1	-	-	-	7
TOTAL REMOVALS	5	3	1	2	2	1	2	1	2	3	2	2	2	1	3	4	7	9	1	-	53
CONFIRMED*	3	2	1	2	-	-	2	1	-	2	1	1	2	1	2	2	1	-	-	-	23
OTHER FAULTS	1	-	2	-	-	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	6
TEST O.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
NO REPORT	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	3
DEFECT AREA																					
GOVERNOR	2	1	-	1	1	-	1	-	1	-	1	1	1	-	1	-	1	-	-	-	12
PUMP	1	-	1	-	-	-	-	-	-	1	-	-	1	-	1	-	1	-	-	-	6
BALL RACE	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	2
MOUNT BUSH	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
OTHER	1	1	-	1	-	-	1	1	-	-	-	-	-	-	1	2	-	-	-	-	8

CUM UNSCH RMVL RATE/1000 UNIT HRS 0.21 CONFIRMED FAULTS/1000 UNIT HRS 0.18

CUM MEAN TIME TO REMOVAL (LIFE) 5690 HRS CURRENT OVERHAUL INTERVAL 9000 HRS

PERCENTAGE OF ITEM LASTING TO OVERHAUL 26

*OTHER REMOVAL WITH MAIN ASSY - MAINTENANCE CONVENIENCE - ETC.
*CONFIRMED FAILURES APPLIES TO UNSCHEDULED REMOVALS ONLY

Figure 7b

Workshop Report

AIRCRAFT TYPE:				
SERIAL NO.	AIRCRAFT & POSITION	HRS RUN	DEFECT	RESULTS OF WORKSHOP INVESTIGATION & ACTION TAKEN
1170109		848 TSR* 9375 TSN†	Losing altitude in turns	Test wing levelling not operative; recalibrated.
0290329		11110 TSR 16771 TSN	Rolls rapidly to right when heading hold engaged.	Various internal outputs were drifting and distorted. Replaced tacho, roll CT and resolver, servo amp and valve amplifier.
0920575		99 TSR 4014 TSN	Altitude hold sloppy in turns.	Roll computer out of calibration limits. Mod D to Lateral Path Coupler embodied to improve interface between Sxxxx equipment and Cxxxx receiver.
1280330		36 TSR 7664 TSN	A/C will not maintain heading — ends up with 30° bank.	No fault found but extensive investigation revealed A3A1A2B output 1.5V — should be zero volts.

CONCLUSIONS

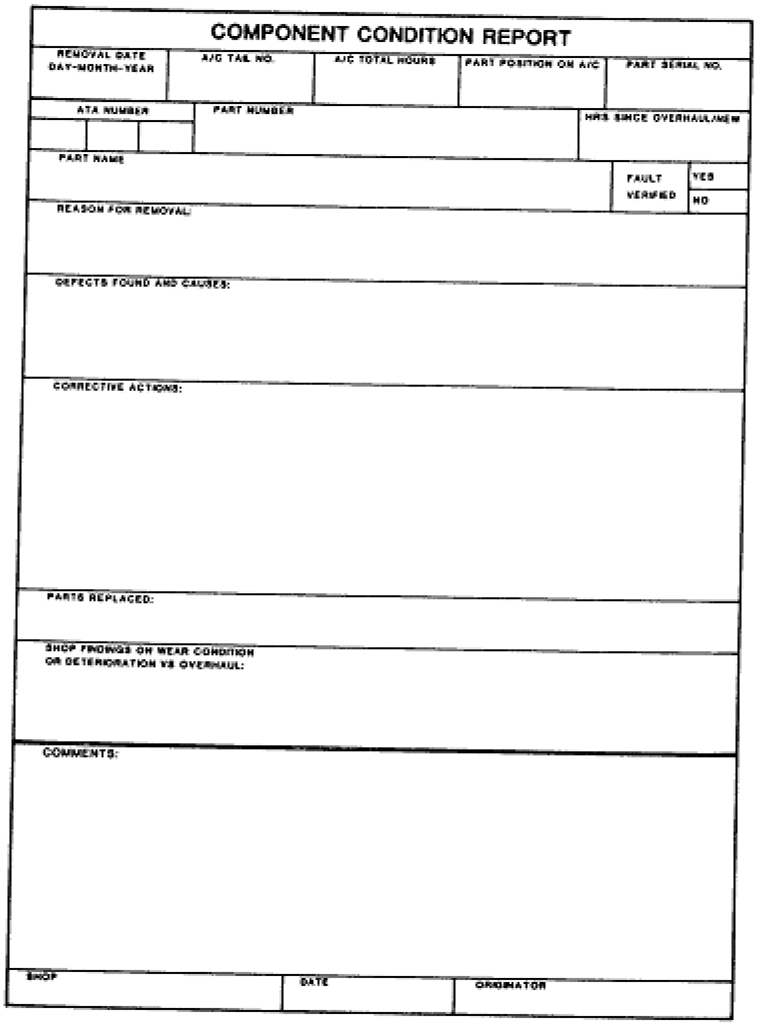
All channel assemblies are now sent to Manufacturer for investigation. Histories are reviewed and any channels which have previous 'NFF'‡ findings are being extensively tested to isolate components which may be drifting out of tolerance. This should result in improved MTBF§, but will probably show more confirmed failures for a while.

REMEDIAL ACTION

	REPORT REF. NO.	PART NO.	ITEM
22-10-14/20 Sheet 1 of 1	1Q75-22-2H	2588812-901	Roll channel assy.

* Time since repaired
† Time since new
‡ 'No fault found'
§ Mean Time Between Failures

Figure 7c



COMPONENT CONDITION REPORT

REMOVAL DATE DAY-MONTH-YEAR	A/C TAIL NO.	A/C TOTAL HOURS	PART POSITION ON A/C	PART SERIAL NO.
ATA NUMBER	PART NUMBER			HRS SINCE OVERHAUL/NEW
PART NAME			FAULT VERIFIED	YES / NO

REASON FOR REMOVAL:

DEFECTS FOUND AND CAUSES:

CORRECTIVE ACTIONS:

PARTS REPLACED:

SHOP FINDINGS ON WEAR CONDITION OR DETERIORATION VS OVERHAUL:

COMMENTS:

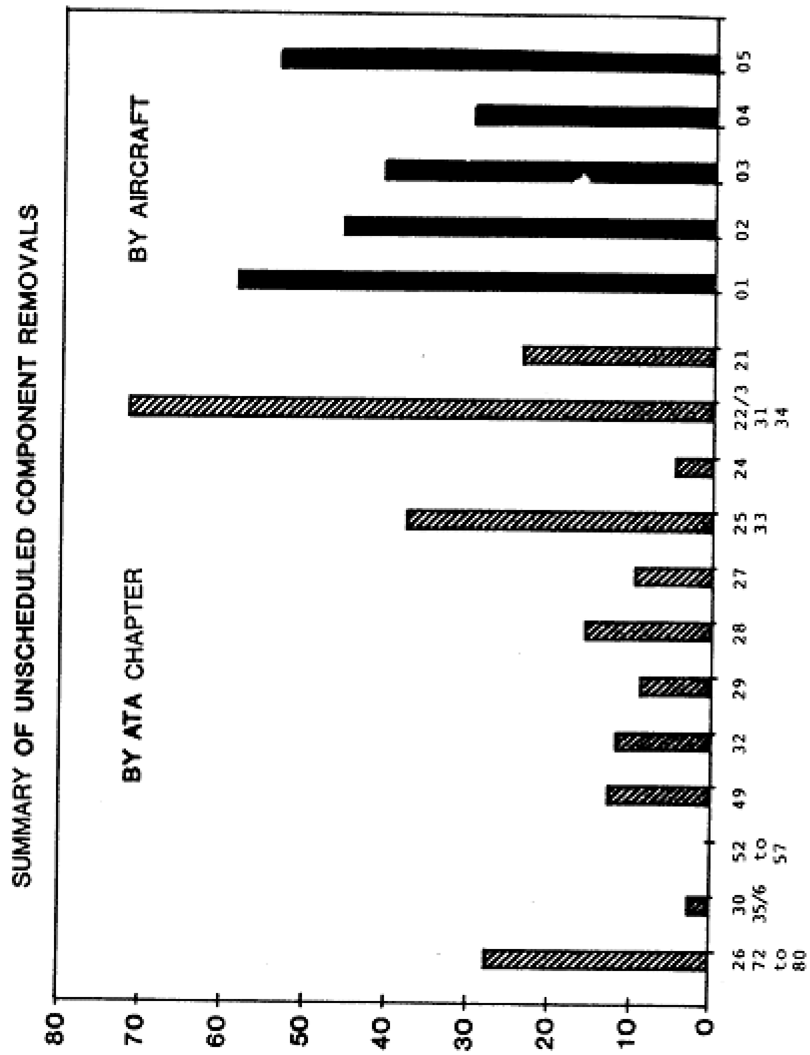
SHOP	DATE	ORIGINATOR

Example 8 -Component removals by ATA chapter and by individual aircraft

The type of display shown in fig. 8 illustrates the relative numbers of components removed from each system, and also shows the distribution of component removals among the various aircraft in the fleet.

While lacking the detail needed to identify specific problem areas, it has the advantage of clearly showing the troublesome systems, and of identifying any aircraft with reliability markedly different from the fleet norm. When combined with similar displays of reported defects and confirmed failures, it can often alert operators to subtle system problems.

Figure 8



<u>**Example 9 -Recalculation of alert levels**</u>

Sometimes, after a period of operation, it becomes apparent that improve-ments in system reliability have rendered the existing alert levels obso-lete. With a good graphic display system, such a situation will be obvious to the naked eye. In these circumstances it is normal to recalculate the alert level, based on current performance, and to display the change as shown in figures 9a and 9b.

Appendix B

Figure 9a

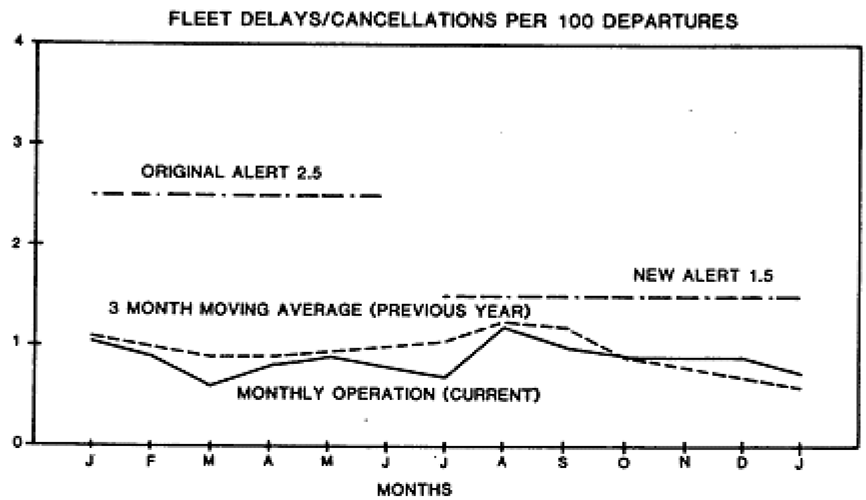
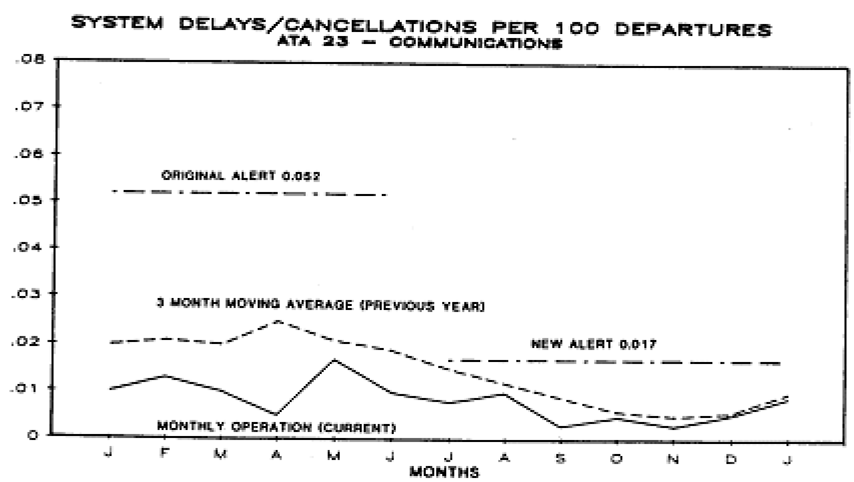


Figure 9b



Example 10 -Component replacement analysis (industry)

The display shown in figure 10 is an example of a computerized printout, provided as part of a multi-participant reliability program. The example shown is just one of a number of different displays used by this type of program, which is intended to supply planning, cost analysis and other management services in addition to reliability monitoring, to operators who do not have the resources to handle all of these functions "in house".

These programs may be "real time, on line", where a computer terminal is installed in the operator's facility, with access to a main computer under the control of the supplier, or alternatively may be "batch" type programs where the operator provides input by mail and receives printouts on a regular basis, usually monthly.

The particular printout shown provides data based on all aircraft of the type which are participating in the scheme, thus enabling each participant to compare his performance with the fleet norm.

Figure 10

COMPS FORM 50 COMPONENT REPLACEMENT ANALYSIS - INDUSTRY

AIRCRAFT TYPE JET COMMUTER — PERIOD COVERED 01-01-68 TO 12-31-68

NUMBER AIRCRAFT REPORTING THIS PRD 114 PREV PRD 109 — TOTAL HOURS FLOWN THIS PRD 71602 PREV PRD 68432

TOTAL LANDINGS THIS PRD 83206 PREV PRD 77491 — AVER DAILY UTILIZATION THIS PRD 1.72 PREV PRD 1.72

AIRCRAFT TOTAL TIME RANGE HIGH 2742 LOW 328 AVER 2105 — TOTAL LANDINGS HIGH 3056 LOW 401 AVER 2445

ITEM	DESCRIPTION		MFR	PART NUMBER	AGENT	TBO MAX	TBO MIN	SCHED RMVLS	UNSCH RMVLS	AVER TAR	TOT UNIT TIME	RATE	PREV RATE
211302	VALVE	SHUTOFF BLEED AIR LH	49286	21482-2B	29868	1200H	1000H	82	11	564H	71602H	0.153	0.216
232101	TRANSCVR	VHF	01785	LTD-62A	78901	OC	OC		123	11M	2736M	0.540	0.987
24271	INVERTER	1000VA	62045	TFD-178-200	50505	1800H	1500H	61	37	868H	143204H	0.259	0.174
261702	ELEMENT	FIRE DETECTOR 6 FOOT	85369	501-10-6		OC	OC		22	1409H	143204H	0.154	0.007
275107	TRANSMTR	FLAP POSITION	10216	1919XY	83401	OC	2400H	11	9	1233H	71602H	0.126	0.259
282703	HEATER	FUEL	08427	90-80-MB-T05	08427	2000H	1600H	26	45	987H	143204H	0.314	0.210
291301	PUMP	HYDRAULIC MAIN SYST	25750	MP1-V5D	38612	1500H	1200H	63	92	535H	143204H	0.641	0.533
324715	BRAKE	MAIN LANDING GEAR	59246	323689-106	38612	250L	2001	264	50	103L	62108L	0.806	0.685
733101	TRANSMTR	FUEL FLOW	29223	3AL-52-PRD1	65243	500H	400H	71	13	292H	43046H	0.310	0.000
733501	INDICATR	FUEL FLOWMETER	29223	3CL-111-CWT3	65243	OC	1000H	13	104	1250H	143204H	0.725	0.707
772501	INDICATR	EGT	95831	28132A	61084	OC	OC		152	941H	143204H	1.061	1.582

Appendix B

Example 11 -Review of service bulletins

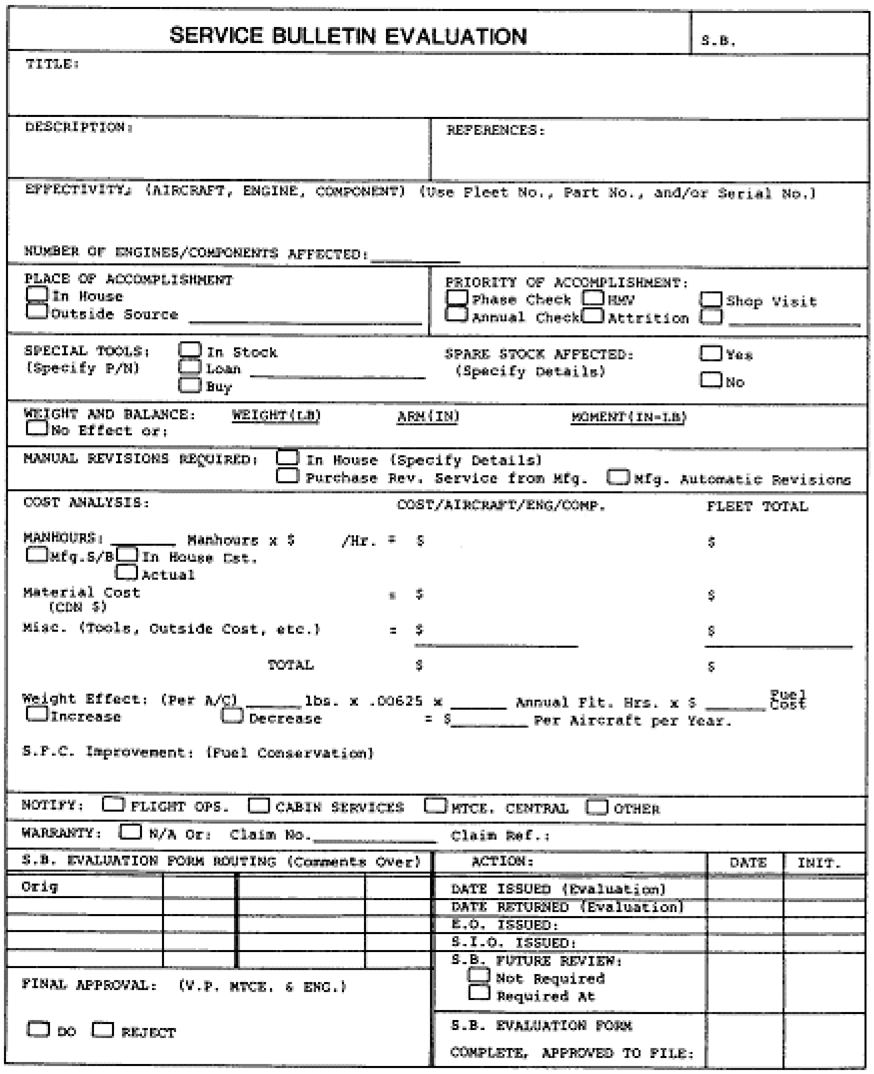
Changes in the manufacturers recommendations must be evaluated to assess their applicability to the operator's fleet. Such changes often take the form of service bul-letins, and a system to evaluate these should be included in every reliabil-ity program. The system can take many forms, from a sub-jective review by the Director of Maintenance, who indicates his decision in the margin of the bulletin (in the case of a small operator), to a full analysis, using MSG-2 or MSG-3 as appropriate, by the reliability control committee, acting as an "internal MRB" (in the case of a large air car-rier).

An example of another method is shown opposite, in figure 11. With this procedure, each element of the technical organization carries out its own assessment of the safety, opera-tional and economic aspects of the bulletin, and makes a recommendation. The senior executive responsible for mainte-nance (usually the vice presi-dent, maintenance and engineering) then makes the final decision.

In the example shown, the recommendations of the various technical depart-ments are entered on the back of the form.

Appendix B

Figure 11



SERVICE BULLETIN EVALUATION | S.B.

TITLE:

DESCRIPTION: | REFERENCES:

EFFECTIVITY: (AIRCRAFT, ENGINE, COMPONENT) (Use Fleet No., Part No., and/or Serial No.)

NUMBER OF ENGINES/COMPONENTS AFFECTED: ______

PLACE OF ACCOMPLISHMENT
☐ In House
☐ Outside Source ______

PRIORITY OF ACCOMPLISHMENT:
☐ Phase Check ☐ HMV ☐ Shop Visit
☐ Annual Check ☐ Attrition ☐ ______

SPECIAL TOOLS: (Specify P/N) ☐ In Stock ☐ Loan ______ ☐ Buy

SPARE STOCK AFFECTED: (Specify Details) ☐ Yes ☐ No

WEIGHT AND BALANCE: ☐ No Effect or: WEIGHT(LB) ARM(IN) MOMENT(IN-LB)

MANUAL REVISIONS REQUIRED: ☐ In House (Specify Details) ☐ Purchase Rev. Service from Mfg. ☐ Mfg. Automatic Revisions

COST ANALYSIS: COST/AIRCRAFT/ENG/COMP. FLEET TOTAL

MANHOURS: ______ Manhours x $ /Hr. = $ $
☐ Mfg.S/B ☐ In House Est.
☐ Actual

Material Cost (CDN $) = $ $

Misc. (Tools, Outside Cost, etc.) = $ $

TOTAL $ $

Weight Effect: (Per A/C) ______ lbs. x .00625 x ______ Annual Flt. Hrs. x $ ______ Fuel Cost
☐ Increase ☐ Decrease = $______ Per Aircraft per Year.

S.F.C. Improvement: (Fuel Conservation)

NOTIFY: ☐ FLIGHT OPS. ☐ CABIN SERVICES ☐ MTCE. CENTRAL ☐ OTHER

WARRANTY: ☐ N/A Or: Claim No.______ Claim Ref.:

S.B. EVALUATION FORM ROUTING (Comments Over)				ACTION:	DATE	INIT.
Orig				DATE ISSUED (Evaluation)		
				DATE RETURNED (Evaluation)		
				E.O. ISSUED:		
				S.I.O. ISSUED:		
FINAL APPROVAL: (V.P. MTCE. & ENG.)				S.B. FUTURE REVIEW: ☐ Not Required ☐ Required At		
☐ DO ☐ REJECT				S.B. EVALUATION FORM COMPLETE, APPROVED TO FILE:		

Example 12 -Global fleet summary

Some manufacturers provide regular reports on the reliability performance of the entire fleet so that individual operators can compare their performance with the norm. Some examples from such a report, in this case published by the Boeing Airplane Co., are reproduced on the following pages. Fig. 12a provides an overall summary of the experience of the reporting operators, fig. 12b shows fleet schedule reliability and fleet utilization, and the histograms in fig. 12c provide a comparison of the individual operators schedule reliability, severity index and utilization with those of the rest of the fleet.

"Severity index" is a means of weighting the severity of schedule interrup-tions according to their effect on operations, in this case using the scale shown below.

	Severity index	
Type	Time (minutes)	Severity
Delay	1 - 15	0.0
Delay	16 - 45	0.1
Delay	46 - 90	0.2
Delay	91 - 150	0.5
Delay	151 - 210	1.0
Delay	211 +	2.0
Cancellation	-	2.0
Air turnback	-	5.0
Diversion	-	5.0

Figure 12a

Figure 12a

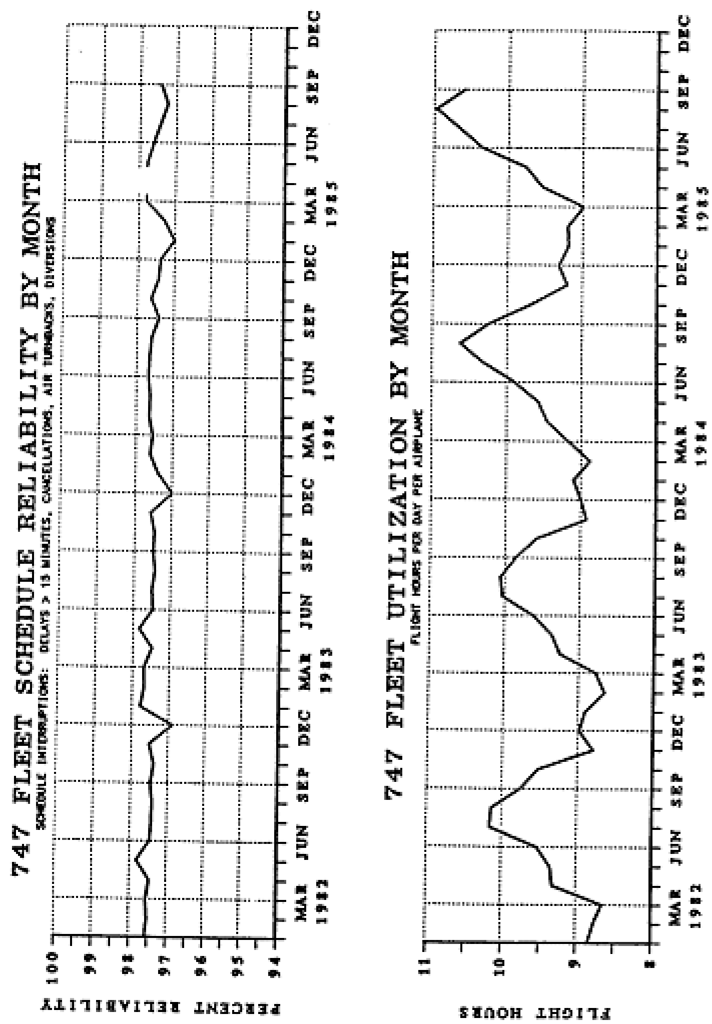
747 AIRLINE SERVICE EXPERIENCE SUMMARY

	COMMERCIAL REPORTING FLEET	NON-REPORTING NON-COMMERCIAL FLEET
NUMBER OF AIRCRAFT	563	44
CUMULATIVE FLIGHT HOURS	17,894,899	181,808
CUMULATIVE LANDINGS	4,546,862	84,679
UTILIZATION (THIRD QUARTER)	10.74 HOURS	
UTILIZATION (LAST 12 MONTHS)	9.80 HOURS	
SCHEDULE RELIABILITY (THIRD QUARTER)	97.36 PERCENT	
SCHEDULE RELIABILITY (LAST 12 MONTHS)	97.48 PERCENT	

HIGH TIME AIRCRAFT - FLIGHT HOURS	PAA N740PA	63,272
- LANDINGS	JAL JA8112	23,180

Appendix B

Figure 12b



Appendix B

Figure 12c

747 SERVICE EXPERIENCE