A NEW SYSTEM FOR COLLECTION AND UTILIZATION OF FIELD DATA ON RELIABILITY AND MAINTENANCE OF WEAPONS SYSTEMS

70/REL 00/1

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AVRO AIRCRAFT LIMITED

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1. INTRODUCTION AND SUMMARY

1.1 Introduction

It is now generally realized that the problem of reliability in modern complex aerial weapons systems is so serious, that a properly co-ordinated Reliability Program must be instituted as an integral part of every project.

A weapons system must pay adequate dividends for the enormous amounts of money invested in its design and development. To do this, a reasonably high percentage of the number manufactured must be serviceable when on call, reliable from take-off to kill, and certain to return to base for turn-around and another mission. This percentage, the measure of reliability, is an important factor when determining the extent by which the improved performance of a new weapons system represents a gain in defence effectiveness.

The RCAF has estimated that with their present-day interceptors, out of any number completing one mission, an average of 55% return unserviceable, and the majority of these require more than 4 hours maintenance. The figures for the vastly more complex interceptors of the Arrow class could be so much worse, that Reliability may well be the most rewarding aspect of the weapons system to which development can be applied. An increase of serviceability from say 50% to only 55% is theoretically equivalent to adding one interceptor to every ten in service!

A logical beginning on such a Reliability Program for the Arrow project has already been made by the introduction of Qualification Testing of all equipment and by aggressive Maintenance Analysis of the design during the development phase. Theoretical Reliability Analysis of some sub-systems is presently being initiated in order to estimate the probable systems-reliability built in during the detail design stage.

The next two phases of the Reliability Program are first to monitor ground testing and developmental flight testing, and secondly to set up adequate communication channels between the Customer and the Company, so as to enable proper assessment and optimization of the performance of the weapons system in service.

1.1 Introduction ......cont'd

It is evident that the existing Field Defect Reporting System is quite inadequate. With present procedures and forms, reporting is too slow, incomplete, and often inaccurate. All relevant and obtainable information is not at present being requested by the Company, partly because the analytical possibilities have not been properly understood. It is essential to know accurately and rapidly not only the nature of malfunctions, but also their relative seriousness, so that the reliability effort can be focussed on the most rewarding problems.

This report is the result of a thorough study of all aspects of Field Data Reporting and Utilization. Systems and ideas in use or envisaged among aircraft and electronics manufacturing companies, airlines, and the services, in both Canada and the United States, have been investigated and compared.

With the addition of original ideas generated within the Company, a proposal for an entirely new system has been developed.

The scope of this system is very extensive indeed, involving initially the associate contractors and all the equipment subcontractors of the Arrow weapons system, and it could eventually be developed into a standard RCAF system. This report is intended to cover in detail only the initiation of the system within Avro Aircraft Ltd's own Flight Operations, but the Company is fully equipped to continue operating the system as support to their aircraft after delivery to the Customer; long term requirements have been taken into account in developing the system. The timing of this proposal is such that the system can be tailored exactly to the Arrow project, since the flight development stage of this aircraft is just beginning. In this manner the system can be perfected in the Company's experimental hangars, before its possible introduction into Customer Service.

1.2 Summary of the Report

1.2.1 What the Industry is doing about Reliability Data (Chapter 2)

A total of twelve different organizations interested in the collection and utilization of field data were visited, or contacted by correspondence. The results of this research are detailed in Chapter 2 of this report.

1.2.1 ....cont'd

The general picture gained was that Avro is not far behind the majority of airframe manufacturers, but at the same time is able to learn from the efforts of the few firms who have already introduced up-to-date Field Data Reporting Systems. Several companies have installed modern filing systems to enable analysis of malfunction data from the aspect of safety engineering, and are now becoming interested in reliability statistics as such. There is some debate on the relative merits of the McBee and I.B.M. punched cards systems, although the latter is generally recognized to be more flexible and much better capable of handling large quantities of data. Douglas Aircraft Company is already employing its I.B.M. 704 computer on defect data analysis.

The greatest mass of relevant experience on field data is in the Electronics industry, where reporting of every defect by means of a pocket-size cheque-book style form, and recording on I.B.M. punched cards, is almost universal. Electronics firms are also furthest advanced in the use of automatic data processing methods and statistical analysis techniques.

The RCAF employs both McBee and I.B.M. systems for filing Technical Failure Reports. A cheque-book style report form for Electronic and Armament Systems has recently been introduced. Utilization of data is at present fairly elementary, but improvements and future developments are under active consideration, and include programs for an I.B.M. 705 computer to be installed around January 1959.

In the airline industry, it has been fully realized that reliability represents large sums of money. Although reporting and recording methods are still largely manual, sophisticated techniques are used in the presentation and utilization of data.

All organizations with experience in Field Data Reporting stressed the point that the field agent is the most critical link in the whole chain. Complete and correct reports can only be achieved by ensuring that the originator is entirely competent and conscientious; he must, therefore, understand fully the reasons why each item of information is required, and be kept fully informed of the action resulting from his reports.

1.2.2 The Defect Reporting and Recording Operations

The field operation of the new system is based on the principle that every failure, defect, or malfunction must be reported, with at most a few days delay. Reporting must identify precisely the unit or units at fault, by system, component and part, as far as the originator is able to trace the trouble. Background information, and an assessment of the extent and time by which the weapons system was at reduced effectiveness, are also required. A new report form has been designed to meet these requirements and is shown in Figure 1.

This form will be issued cheque-book style, in the size of the illustration. No more than two people should be concerned in completing the report. A separate return is required for each defective part; the questions are specific and the back of the form is available for additional narrative information. It is believed that the form is not excessively demanding, although its success in customer service would depend on field agents being properly selected, thoroughly sold on the system, and fully supported. The system has been designed to meet the requirements of reliability analysis rather than to conform to present practice.

In many cases the originator will have no means of knowing which part is defective, nor the cause of trouble. The record of the defect will then be completed when the overhauler's inspection report is received, but in the meantime the incomplete defect report has many uses.

Reporting on engines, integrated electronics and missiles will be arranged in conjunction with the separate contractors concerned, so that Avro can maintain a watch on the reliability of the complete weapons system. Engine, electronics and missile contractors will be asked to collect all the data which Avro requires.

The recording operation back at the plant will be based on an I.B.M. system. Each Field Defect Report form will give rise to at least one I.B.M. card, as shown in Figure 2; the report form and I.B.M. card have been designed simultaneously, so that they are fully compatible. Fairly elaborate code systems are necessary to represent the reported data by means of the available 80 letters or numbers. The coding is done by the technicians who first screen the reports for completeness and accuracy on arrival at the plant.

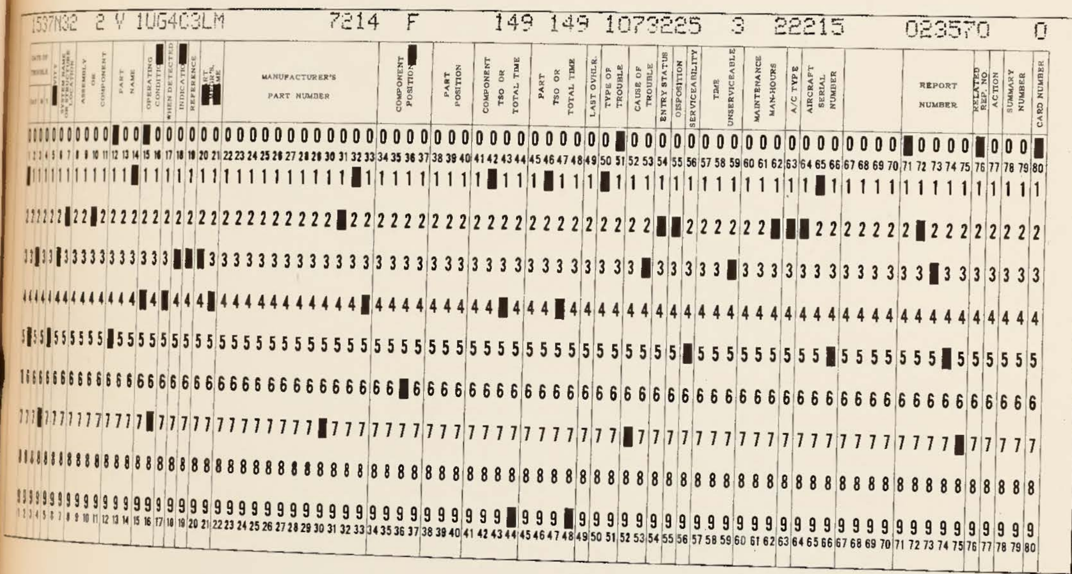

FIG. 2 THE IBM CARD

(CORRESPONDING TO THE REPORT IN FIG. 1)

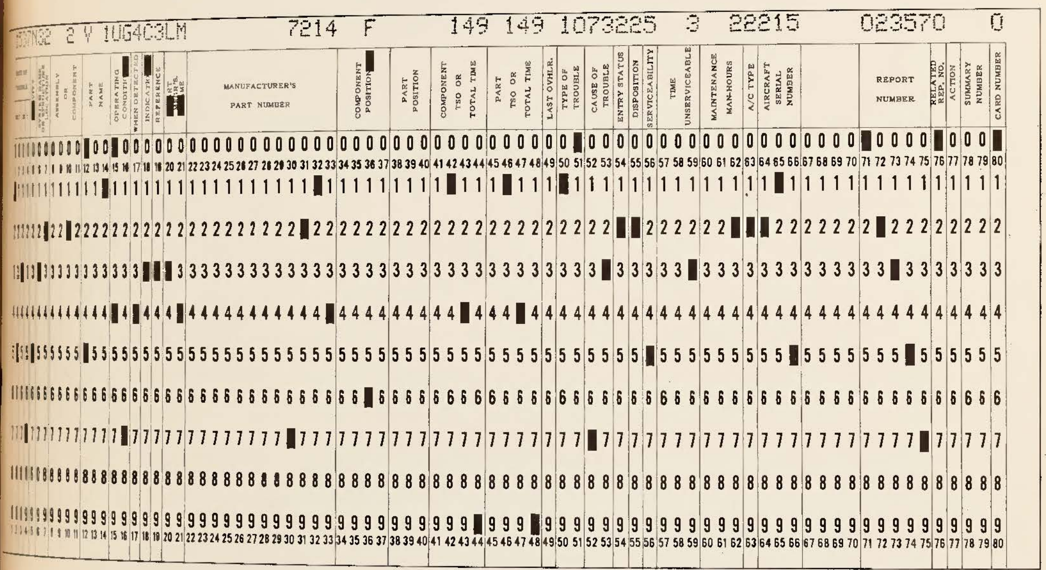

FIG. 2 THE IBM CARD

(CORRESPONDING TO THE REPORT IN FIG. 1)

FIGURE 4 - EXPLANATION SHEET

Date of Defect	1538 means 15 Mar. 1958 19N7 means 19 Nov. 1957
Activity	Coded e.g. N = North Bay, U = Uplands
System Name or Structure Location	Avro D.C. numbering system e.g. 32 = Flying Control Hydraulics
Assembly or Component	Coded e.g. 02 = Compensator; 11 = 40 GPM Filter; 18 = Elevator Parallel Servo
Part	Coded e.g. V1 = Valve; E2 = Filter Element
Operating Condition	Coded e.g. UU = Unknown; 42 = 30-40,000 ft. & 1.25-1.75 M
When Detected?	Coded e.g. E = As in Operating Condition, normal flight; 5 = 25 hr. Inspection.
Reference	3 = "Part" card; 2 = "Component" card
Indication of Trouble	Coded e.g. C = Inoperative; P = Visual Examination
Part Manufacturer	Coded e.g. PM = Porous Media; VI = Vickers
Component and Part Position	E & R numbers of Electrical and Electronic Equipment. Others: e.g. F = Forward; SU = Starboard Upper

Component and Part Time	Recorded (TSO)
Last Overhauler	Coded e.
Type and Cause of Trouble	Self-cod cover of
Entry Status	Indicate tion on etc. e.g. 1 = 3 =
Disposition	Self-cod
Serviceability	Self-cod
Time Unserviceable	Time in for this
Maintenance Man-Hours	Man-hour remedy
Aircraft Type	1 = Arr
Related Report Number	FDR's or number, Isolate

FIGURE 4 - EXPLANATION SHEET

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. 1958 19N7 means 19 Nov. 1957

rth Bay, U = Uplands

ng system e.g. 32 = Flying
s

ompensator; 11 = 40 GPM Filter;
allel Servo

alve; E2 = Filter Element

nknown;
0-40,000 ft. & 1.25-1.75 M

in Operating Condition, normal
r. Inspection.

2 = "Component" card

operative; P = Visual

orous Media; VI = Vickers

Electrical and Electronic

Forward; SU = Starboard Upper

Component and Part Time	Recorded in hours since new or last overhaul (TSO)
Last Overhauler	Coded e.g. ☆ = Manufacturer; 1 = Jarry
Type and Cause of Trouble	Self-coded. List on FDR, continued inside cover of book of FDR's
Entry Status	Indicates source and reliability of information on Cause of Trouble, Part responsible, etc. e.g. 1 = Reporter's guess; 2 = Reporter certain 3 = RCAF Investigation
Disposition	Self-coded on FDR
Serviceability	Self-coded on FDR
Time Unserviceable	Time in hours which A/C would have been U/S for this defect happening by itself
Maintenance Man-Hours	Man-hours which would have been necessary to remedy this defect happening by itself
Aircraft Type	1 = Arrow 1; 2 = Arrow 2; etc.
Related Report Number	FDR's on related defects have same report number, and number 1, 2 ... in this space. Isolated FDR's have zero here.

DATE OF DEFECT	ACTIVITY	SYSTEM	COMPONENT CODE	PART NAME CODE	OPERATING CONDITION	WHEN DETECTED	INDICATION	REFERENCE	PART MANUFACTURER	MANUFACTURER'S PART NUMBER	COMPONENT POSITION	PART POSITION	COMPONENT TIME	PART TIME	LAST OVER-HAULER	TYPE OF TROUBLE
1538	N	32	2	V 1	UG	4	C	3	LM	7214	F		14 9	149		10
1888	U	32	11	E 2	UU	5	P	3	PM	7403T	S		12 5	125		26
PARTICLES FROM DAMAGED SEAL IN ELEV PARALLE SERVO RUDDER AND AILERON FILTERS CLEAN																
1888	U	32	18	S 3	UU	5	O	3					42 5			16
SLIGHT LEAK ALSO FOREIGN MATTER IN FILTER																
2948	L	32	10	D 4	42	E	N	3	V1	4295RP	SU		29 6	296		66
969	U	32	19	R10	21	E	M	3	MH	73079	P		8 1	81	1	66
1748	L	32	1	O 1	UU	3	F	3	PK	532410	S		7 2	72		45
1078	U	32	29	N 3	UU	4	B	3	AE		S		21 9	219		5
NEEDLE ON GUAGE FELL OFF SUGGEST BETTER MOUNTING TO REDUCE VIBRATION																
719	M	32	09	P 8	UU	4	O	3	BX		P		1 9	19		45
GAUGE SHOWED ZERO ON DISCONNECTING NITROG LINE FLUID RAN OUT INDICATING LEAKAGE PAST PISTON THIS IS THIRD TIME IN LAST TWO WEEK																
1359	L	32	17	B 5	04	9	C	3			P		9 2		*	66
CONTROLS JAMMED ON COCKPIT CHECK NEED MORE INFO RE TROUBLE SHOOTING THIS SNAG MUCH TIME LOST DUE TO LACK OF EXPERIENCE THIS AC																

FIGURE 3

	MANUFACTURER'S PART NUMBER	COMPONENT POSITION	PART POSITION	COMPONENT TIME	PART TIME	LAST OVER-HAULER	TYPE OF TROUBLE	CAUSE OF TROUBLE	ENTRY STATUS	DISPOSITION	SERVICEABILITY	TIME U/S	MAINT. MAN-HOURS	A/C TYPE	A/C SERIAL NUMBER	REPORT NUMBER
M	7214	F		14 9	149		10	73	2	2	5	3	2	2	215	2357
M	7403T	S		12 5	125		26		2	3	5	12	8	2	308	2627
E	D SEAL IN ELEV PARALLE															2627
E	RON FILTERS CLEAN															2627
				42 5			16	51	2	4	5	12	2	2	308	2627
E	IGN MATTER IN FILTER															2627
1	4295RP	SU		29 6	296		66	2	2	5	8	5	4	2	239	1421
H	73079	P		8 1	81	1	66	27	2	4	*	29	16	3	503	2439
K	532410	S		7 2	72		45	77	2	5	5	6	11	2	274	1404
E		S		21 9	219		5	75	2	5	9	1	1	2	334	2593
	OFF SUGGEST BETTER															2593
I	BRATION															2593
X		P		1 9	19		45	77	1	5	5	3	2	3	539	2716
O	N DISCONNECTING NITROG															2716
N	DICATING LEAKAGE PAST															2716
	TIME IN LAST TWO WEEK															2716
		P		9 2		*	66	73	2	5	*	12	16	3	612	2722
O	CKPIT CHECK NEED MORE															2722
T	ING THIS SNAG MUCH															2722
K	OF EXPERIENCE THIS AC															2722

FIGURE 3

1.2.2 ....../cont'd

The narrative content of the report is also recorded on I.B.M. cards (known as "Trailer" cards). A synopsis of the story is punched letter by letter, using as many cards as may be required.

A typical I.B.M. tabulation ofField Defect Reports on the Arrow Flying Controls Hydraulic system is shown in Figure 3. Figure 4 is an Explanation Sheet which will go with every tabulation, to make the print-off intelligible to persons unfamiliar with the codes.

1.2.3 The Analysis and Action Organization (Chapter 4)

It is proposed that the co-ordinating centre of the whole Field Data System should be the Maintenance and Reliability Section of the Equipment Design Department of the Engineering Division. Figure 5 illustrates how the system will function.

The Statistical Reliability Analysis and Reliability Engineering groups of this section will be responsible for analysing the defect reports, spotting and rating problems, and initiating corrective action in the appropriate department of the Company. The Reliability Engineering Group also has the important responsibility of seeing that the corrective action taken is reported to the data collecting organization, so that summary reports and individual action reports can be circulated to field agents.

The Reliability Analysis Group first receives Field Defect Reports in the form of a tabulation of the day's I.B.M. cards from the I.B.M. operation. Unusual or critical Field Defect Reports have already been discovered at Screening and acted upon by Reliability Engineering. Inspection of the daily tabulation will suggest lines of analysis, which are then followed up by means of special tabulations and summaries, making use, where necessary, of digital computing facilities and employing reference and utilization data, as shown in Fig. 5. The analytical approach is summarized, and the links with the Maintenance Engineering Group and with the Technical Design Department are explained, in paragraph 1.2.4.

1.2.3 ..../cont'd

The Reliability Engineering Group takes over when problem areas have been pin-pointed by the Reliability Analysis Group. Working with the approval of Project Management, they will initiate action in the appropriate departments, and will also deal with equipment vendors, in conjunction with the Procurement Department. The Reliability Engineering Group will also be responsible for keeping appropriate functions throughout the Company informed on the current reliability picture.

1.2.4 <u>Philosophy and Techniques of Analysis</u>

One of the most important innovations now being proposed is that continuous Operations Analysis should be carried out to ensure that engineering effort on so called "non-critical" defects is most usefully applied. The major portion of field defects are of this nature; they are dealt with on the spot by normal maintenance procedures, and engineering action is not immediately required. These defects are more or less serious according to their frequency, the down-time they cause, and according to the role to which the weapons system happens to be assigned, whether it be operational readiness, familiarization and training, or some other duty. Under the present system of reporting and analysis it is impossible to assess accurately the relative seriousness of these defects.

The new Field Defect Report form will enable Avro

(i) to measure the seriousness of defect rates in their effect on the serviceability of the weapons system,
(ii) to tackle equipment reliability problems in the manner giving most improvement per dollar invested, and
(iii) to plan the attack on each problem in a much more scientific manner than has been possible hitherto.

The first step is to produce for each type of defect a weighted defect-rate which quantitatively represents its contribution to the unserviceability of the weapons system. Using these figures, and measuring the progress of corrective measures on each problem, the allocation of engineering effort among various problems can be continuously optimized.

The attack on each problem will then be planned in four directions:

1.2.4 ..../cont'd

(i) Design improvement. This will be facilitated by statistical correlation between defects and the various reported factors that might be contributory.

(ii) Optimization of preventative maintenance by adjustment of overhaul and replacement schedules.

(iii) Improvement of maintenance techniques and inspection procedures by means of studies of manhours and down-time.

(iv) Optimization of logistic support of maintenance by ensuring availability of equipment and by inventory control of spare parts.

This plan will be put into effect by engineering personnel of the Equipment Design Department.

Reliability Analysis of sub-systems will be reviewed periodically as better statistics are accumulated, and also at the request of the Technical Design department when design changes may require a compromise between reliability and system performance. Serviceability Analysis of the complete weapons system will also be available to the appropriate department, for incorporation in optimization studies along with such other weapons system components as radar range, speed, manoeuvrability, missile performance, etc.

2. WHAT THE INDUSTRY IS DOING ABOUT RELIABILITY DATA

2.1 Introduction

In order to become familiar with the broad field of Reliability and all its aspects, several visits were made to Aircraft Manufacturers and Airlines in the United States and Canada. In addition, contact was established and corrsspondence was exchanged on the subject of Reliability wherever it was felt that useful information might be obtained.

The following is a list of establishments that have provided useful information for our investigation into the best type of Field Data Recording System for the accumulation of statistical data for Reliability Analysis:

(a) Chance Vought Aircraft, Dallas, Texas
(b) Convair, Fort Worth, Texas
(c) Northrop Aircraft, Hawthorne, California
(d) Douglas Aircraft Co. Inc., Santa Monica, California
(e) The Martin Company, Baltimore, Maryland
(f) United Air Lines, San Francisco, California
(g) Canadian Pacific Airlinss, Vancouver, British Columbia
(h) Trans Canada Air Lines, Montreal, Quebec
(i) Canadair, Montreal, Quebec
(j) R.C.A., Camden, New Jersey
(k) Orenda Engines Limited, Malton, Ontario
(l) R.C.A.F., A.M.C.H.Q., Rockcliffe, Ontario

Where visits were made to some of the above mentioned plants, their reliability programs were investigated in detail. A great deal of information was obtained such as Organizational Breakdowns, Code Systems, sample McBee and I.B.M. cards, Reliability Programs, etc.

For presentation in this report, only the essential details are included which indicate the extent to which each company is pursuing the problem of Reliability.

From a preliminary investigation it was known that the two most widely used methods of recording Field Data were the McBee Card System and the I.B.M. Card System. Our decision to use the I.B.M. Card was made after discussing the use of the two systems with the various firms listed above, and analysing our own requirements.

2.2 Chance Vought

Chance Vought and Convair were first contacted through their Flight Safety Engineers.

This group, under the supervision of a Staff Engineer, Cockpit Design and Flight Safety, report directly to the Chief of Design.

Chance Vought's interest in the reliability of airborne equipment stemmed from an interest in the safety of the aircraft and all equipment whose malfunction might lead to the damage of or loss of the aircraft. It was obvious to Chance Vought that a quick and accurate method of accumulating reliability data on airborne equipment was necessary.

Malfunction reports originated from four sources:
- (a) The Field Technical Representative (Service Dept.).
- (b) The Field Engineer (Engineering Dept.).
- (c) The Quality Control Engineers (Production).
- (d) The U.S. Navy.

It was found that for one typical malfunction, four different forms were used and four different reasons for malfunction were sometimes reported. Essential data was missing and only approximately 10% of the actual malfunctions were reported.

Chance Vought's solution to this problem was to design one Field Failure Report Card for the use of all people originating malfunction data. The card contained headings for all vital information that was necessary to carry out a sound reliability program. The data is transcribed to I.B.M. cards at the plant and periodic "print-offs" are produced to present statistical data to Engineering, Management, Production, Procurement, etc.

The Flight Safety Group still transcribe their information to McBee Cards, since the number of returns that they are interested in, from a flight safety standpoint, is relatively small.

2.3 Convair, Fort Worth

As with Chance Vought, the organization of an efficient data feed-back system was instigated by the Flight Safety Group. This group reports to the Chief of Service Engineering under the Assistant Chief Engineer - Product Design. Although their reasons for

2.3 ....cont'd

collecting failure data are based on the safety aspect rather than for maintenance evaluation, the problems are the same.

Their malfunction reports originate from three sources:
(a) Field Service Representative (Service Dept.).
(b) Field Engineer (Engineering Dept.).
(c) U.S.A.F.

The same trouble was experienced with these reports as with those of Chance Vought. The information was found to be sketchy, incomplete, inaccurate and only a small portion of the malfunctions were reported.

The lack of interest, initiative, and awareness of the problem on the part of the originator was believed to be the main problem. Without a complete, concise and accurate report, proper analysis of malfunctioning equipment is impossible.

Convair were in the process of starting a McBee Card System. The information coming in from the Field Service Engineers and Service Representatives will be transcribed from the standard type defect reports to the McBee Cards. Convair admitted that they had not considered the I.B.M. system too seriously at that time due to the suspected complication of the coding system. They reported that the U.S.A.F. were studying the use of the McBee Card for failure reporting, but discussions with other manufacturers later in our investigation proved that this was not necessarily true. The U.S.A.F. are currently applying the I.B.M. system to selected 1st line aircraft and related support equipment, but it is intended to extend it to all weapons systems throughout their life cycle at a later date. It is planned to issue the collected data as monthly Malfunction Reports to Design, Quality Control and the Service Groups.

2.4 <u>Canadair, Montreal</u>

Canadair had considered the use of a McBee or I.B.M. card system for field data reporting. Mr. J. Heine had recently completed a trip to the United States to investigate this problem. However, they were still relying on the conventional system of U.C.R.'s and Defect Reports at the time of our visit. They did go to the point of coding the defect information on cards, but the job of extracting the information was obviously great and precipitated Mr. Heine's trip to the United States.

2.4 ....cont'd

A monthly Defect and U.C.R. Status Report was issued, but no attempt was made to analyse the defect situation or to present a complete picture to the Designer on the performance of his airborne equipment.

They did agree that the existing method was inadequate and were keenly interested in our investigation into applying automatic accounting techniques and statistical computations to a Defect Reporting System.

2.5 Trans Canada Airlines, Dorval

The subject of Field Defect Reporting was discussed with the Superintendent of Inspection at Dorval, who is responsible for maintaining statistics on every item of equipment and structural component on Trans Canada aircraft. Their prime concern is to ensure that the life of all equipment in service is recorded so that accurate maintenance and overhaul schedules may be set up.

Reports on malfunctions are originated by the inspector in charge or by the crew chief. They are directed through the Maintenance Superintendent to the Inspection Department where the information is transcribed to a Remington Rand Failure Card. A flag system is used at the bottom of the card to indicate the total number of malfunctions of that particular item of equipment and is adjusted every time a malfunction occurs. If it reaches a predetermined rate of malfunction, the flag automatically indicates red and the unit is removed from service until a 'fix' is originated and incorporated. The method of calculating the critical rate of malfunction was not determined but is probably based on previous experience - for example, so many malfunctions for a certain number of flying hours. In this way trends are anticipated before the situation becomes serious.

Contrary to the general trend in the aircraft industry, the airlines are more progressive in the matter of presenting maintenance and operating statistics to management. This is undoubtedly due to the fact that these statistics indicate the "in commission" state of their aircraft, which can easily be translated to dollars and cents. It is felt that the effect of serviceability on the combat effectiveness of our weapons system is just as important to Avro.

A monthly report is issued to their Management on all types of malfunctions and flight delays. This report is fairly detailed as to the reasons for the delay or malfunction.

At the present time, T.C.A. is investigating the McBee Card system to replace the Remington Rand System in order to speed up the sorting of data for analysis and presentation to management.

2.6 R.C.A., Camden

R.C.A. have been actively interested in the subject of Reliability for a number of years. R.C.A. realized the importance of a rapid and efficient feedback of failure and deficiency data if a comprehensive analysis of reliability were to be possible.

Of all the firms we contacted, it would appear that R.C.A. has advanced furthest in this field. They have had an I.B.M. failure reporting system in operation for over three years and have reached the point now when the whole system operates very smoothly and efficiently and provides excellent statistics for reliability analysis.

The control centre for the feedback system is located in the Customer's Service Department at Cherry Hill. Here, the data is transcribed from the R.C.A. Field Card to I.B.M. cards, checked for technical accuracy, sorted and filed. The design of the R.C.A. Field Card is the result of two years of development by the U.S.A.F. and R.C.A. and they stressed the importance of simplicity of layout, and the necessity of ensuring that all of the vital information was supplied from the field.

The Field Cards are originated by R.C.A. Field Engineers, Service Representatives, Members of the U.S.A.F., Standards Group, Reliability Engineers and Test Personnel conducting breadboard tests.

R.C.A. stressed the importance of feeding results back to the field to build up a feeling of interest and confidence in the system in the originators of defect information.

Approximately 3000 malfunction reports a month are handled on Airborne Fire Control Systems by the Control Centre. The staff necessary to handle these reports consists of not more than two or three people. The key man must be a type described by R.C.A. as "Engineer Material" - a well qualified and intelligent technician - with some experience in the type of equipment being processed, and an interest in reliability and statistics.

The Reliability Program is extensively organized at R.C.A. and emcompasses the complete life cycle of the equipment, including Preliminary design, Breadboard development, Purchasing, Qualification, Production and Service Life.

2.6 ....cont'd

Their Reliability Group has a representative in each Design Group to ensure that all aspects of reliability are coordinated on that particular project. He ensures that trouble areas, which are pin-pointed by the Reliability Analysis Group, are investigated by design and the proper action is taken to improve reliability. On special field projects, Reliability Engineers are sent out to monitor the feedback of failure reports to the Control Centre.

Their Standards Group play an important role in the Reliability Program. They are responsible for:

(a) Analysing qualification tests, to rate Vendors.
(b) Testing and evaluating components to engineering specifications.
(c) Recommending preferred units of equipment for use in new systems.

It was of particular interest to note that the R.C.A. Reliability Group is using their punched card system to record reliability statistics in the performance of equipment as early as the Bread-board Stage. This would correspond to the recording by Avro of data from the Systems Test stage.

All details of the proposed layout of the Avro Field Defect Report Form were discussed with R.C.A. and many valuable suggest-ions were made by them.

As discussed elsewhere in this report it was mutually concluded that the Astra 1 system would be adequately covered by the present R.C.A. reporting system. Details of additional performance statis-tics required by Avro for operations analysis were passed on to R.C.A. for their perusal. This will be the subject of further meetings with R.C.A.

2.7 The Martin Company, Baltimore

Of the Aircraft Manufacturers that were contacted, the Martin Company was the most advanced in Field Data Reporting on aircraft structures and airborne systems.

The importance of reliability of the complete weapons system has been appreciated for several years by the Martin Company. They found that the reliability of a weapons system might be impaired by a condition so simple to correct that it was not considered worthy of serious investigation. However, a highly technical problem was usually considered to be serious. The latter problem

2.7 ....cont'd

received much more attention, although it might be uncommon or limited to one unit. The simple problem might be widespread and have an overall greater effect on the reliability of the complete weapons system.

A Service Trouble Report was designed, similar to the R.C.A. Field Defect Report. This report is used by Engineering, Quality Control, Manufacturing and Customer Service to feed trouble data into an I.B.M. Tabulating system.

In all cases where any unsatisfactory condition is noted, whether the parts involved or the action taken apply to an outside vendor, the Martin Company, or the Customer, a Service Trouble Report is written. The headings on the Martin Service Trouble Report are basically the same as R.C.A.'s and the presently proposed Avro Card. The policy has been established that as many cards as possible are to be written and that each card must be filled in completely.

In the field, the card is originated by the Company Field Representative and forwarded to the Customer Service Department. The group responsible for that particular project codes the card and determines whether the Service Trouble Report is "Critical", for "Routine Action", or for "Information Only".

If the Report is "Critical" a Service Action Card is prepared and sent to the responsible body in Engineering for corrective action. This card serves to ensure that the malfunction is investigated and that a satisfactory "Fix" is established. The Service Trouble Card is filed in the Customer Service Department for tabulation.

The Corrective Action, which must be written on the Service Trouble Report is transmitted to the field by a periodic review of all Trouble Reports upon which corrective action has been taken. This review, the Service Action Review, ensures that the man in the field is kept in the picture and helps to establish confidence in the Defect Reporting System.

A periodic machine tabulation is issued to Engineering, Quality Control, and Manufacturing and consists of a compilation of all Service Trouble Reports to date and pin-points the responsibility of each defect. This has the tendency to speed up the origination of a fix in order to get a particular malfunction deleted from the periodic report. The seriousness of any defect will be indicated by the number of times it appears on the periodic tabulation.

2.8 Northrop Aircraft Inc., Hawthorne, California

Contact with Northrop was established through the Flight Safety Group (Airworthiness). This group is responsible for gathering malfunction data by two methods, a McBee Punched Card System and an I.B.M. Tabulating System. Similar to Chance Vought and Convair, their interest in Field Data Reporting Systems stemmed from a desire to gather data on airborne equipment failures affecting the safety of the aircraft. As the number of returns increased, it was necessary to progress from the relatively simple McBee System to the more efficient I.B.M. Tabulating System.

Information regarding their I.B.M. Code System and sample cards was received by Avro, but the extent to which this system is being used in Reliability Analysis, and the organizational details of this endeavour were not determined since a visit was not made to Northrop. It would appear however, that the Martin Company has advanced further in the field of reliability engineering.

2.9 Douglas Aircraft, Santa Monica

A visit was not made to Douglas Aircraft on the subject of Field Data Reporting or Reliability, but some information has been received which indicates that they are using the I.B.M. Tabulating Method to accumulate field data on equipment reliability.

A Douglas Flow Chart of their malfunction report processing indicates that a Reliability Program equal to that of R.C.A. or Martin does exist. Malfunction reports are originated in Manufacturer Operated Field Stations, Manufacturing Facilities, Military Training and Operation Sites. Under Manufacturing, reports emanate from Receiving Inspection, Production Testing, Production Inspection and Testing and Calibration Laboratories. These reports are sent initially to local reliability groups where they are checked, coded and transcribed to I.B.M. Cards. They are then forwarded to the Main Reliability Section in the Engineering Department where the data is processed, analysed and issued in the form of reports to all people concerned with proposed remedial action.

2.10 United Air Lines, San Francisco

United Air Lines were contacted to determine the airline approach to the problem of malfunction reporting and reliability.

They are presently using a manual card system, similar to Trans Canada Air Lines, to record data on the malfunctioning of airborne equipment. United Air Lines are investigating the use of an I.B.M. tabulating system, but it is still in the preliminary planning stage.

2.11 Orenda Engines Limited, Malton, Ontario

Orenda were found to have quite a sophisticated I.B.M. system for handling Field Defect Data, which had been in operation about 2 years. Several useful visits and phone calls were made to Orenda, on account of the ease of communication with them.

Their system was based on advice from the Pratt and Whitney Engine Company, and was installed initially with the main objective of streamlining the handling of data. A small amount of statistical analysis had been done with the help of a U.S.A.F. report on actuarial methods for predicting engine life.

Orenda really has two parallel systems, with separate I.B.M. layouts: "Engine Removal Analysis" and "Serialized Accessory Removal Analysis". Data is reported on a straightforward 8½" x 11" sheet. They are on the point of introducing a third system with a separate report form and I.B.M. card, "Parts Replacement Analysis". The "Serialized Accessory Removal Analysis" records the accessory removal and also the part found primarily responsible for the failure of the accessory. This information is found very valuable by Orenda although not primarily their responsibility. The Part information is obtained from the overhauler via the R.C.A.F., on a copy of the R.C.A.F. L53, which is the overhauler's report on the condition of the unit. The "Parts Replacement Analysis" is being set up to keep a detailed check on all failed parts of Orenda's own design.

Data is coded and transcribed from the report form to a layout form before key-punching. The code system is very elaborate and "analysts" are employed to carry out this process. Frequent conferences are necessary to modify the code books in the light of experience, and one complete repunching of the existing cards was done after a major modification. Orenda have hopes of redesigning their field forms to put most of the work of coding onto the Field Representative, since they find it very difficult to get suitable men and keep them interested in the coding job as existing at present.

I.B.M. cards are also employed to tabulate a synopsis of the narrative report from the field, and have been found most useful to back up coded data.

At Orenda, Field Data is handled by a Service Engineering Group, which consists of engineers reporting to the Service Manager and this group provides a link between the Service Department and the Engineering Department.

2.12 Air Materiel Command Headquarters, RCAF Station, Rockcliffe, Ontario

Field Data processing in the RCAF is the responsibility of the Logistics Data/Statistical Services section at AMCHQ. All Technical Failure Reports from the field are received by this section, which issues Monthly Defect Summaries, regular Failure Analysis reports, and special reports of many kinds. The summaries and reports are used chiefly by Specialist Officers of the Logistics Staff, each responsible for a small number of equipment items.

Defects on Electronic and Armament Systems are reported individually on a recently introduced cheque-book style form (March 1957), and recorded on I.B.M. punched cards. Defects on all other kinds of airborne equipment are reported by listing on a Technical Failure Return, which separates lifed and non-lifed items and has space for reporting eleven defects on each side. This data is recorded on McBee cards.

The Technical Failure Return in the case of non-lifed equipment calls for only identification of the failed unit and a brief indication of the type of failure. For lifed items, details of the last overhaul, hours in use, and some details regarding the failure are asked for. The Electronics and Armament Form calls for similar information, with check-off boxes for details of the failure; the back of the form is used for additional comments where relevant. This form closely resembles the standard Electronics Failure Report form used by R.C.A.

In cases where maintenance personnel wish to draw attention to an unusual defect or a series of recurring troubles, the universal RCAF Unsatisfactory Condition Report form is used. Data reported by UCR is recorded in the same way as routine data, but a reply is sent back in due course to the originator.

The number of defect reports received by AMC has reached 12,000 per month on Electronics and Armament and 5,500 per month on other equipment. The number of reports on Electronics and Armament doubled during the first four months after the introduction of the cheque-book style report form. The personnel handling this quantity of information consist of 8 clerks and 6 RCAF specialist personnel ranging in rank from Flight Sergeant to Flight Lieutenant.

2.12 ....cont'd

The amount of clerical work required with the McBee card recording system is much greater than with I.B.M. cards, and the sorting possibilities of the card presently in use leave something to be desired. On the other hand one McBee card can accommodate much more information than one I.B.M. card, unless extensive code systems are used. AMCHQ have not as yet seen their way to producing code systems for equipment other than Electronic and Armament Systems. On these systems the actual report form is punched as an I.B.M. card, and the screening and coding necessary, before punching, is carried out by two specialist technicians who are still able to do some other duties in addition.

The section visited at AMCHQ is not carrying on any statistical analysis of the data other than the preparation of a wide variety of tabulations, bar charts, pie-graphs etc., for use by the Logistics Specialist Staff. An attempt at actuarial analysis of engine failures was frustrated by smallness of sample.

There exists, however, a separate analysis section at AMCHQ, working on further uses of the available data, including the application of an I.B.M. 705 computor to be delivered around January 1959, and on new ideas for data collection.

3. THE DEFECT REPORTING AND RECORDING SYSTEM

3.1 A Unified System

The proposed Field Data program has been designed from the outset as an integrated system. It centres around a new report form and an I.B.M. card. The report form is an improved means of communication between the Field and the Company, and the I.B.M. card is the key to ready access and speedy analysis of the information received. The two have been designed for compatibility, but the content and layout of the report form have also been determined by careful analysis of what can be achieved practically in the Field. At the same time the I.B.M. layout is adaptible to very varied utilization, including the sophistated computing techniques which will be called for when sufficient data has accumulated.

3.2 Coverage of the Complete Weapons System

Early attempts were made to design a common report form which could be used for all major components of the Weapons System -- engines, electronics and missiles, as well as airframe. This idea was dropped when the detailed requirements of the manufacturing companies involved were examined. Such a universal report form would be beyond the acceptable limits of size, because of the need to provide additional spaces useful to only one or two of the companies. A common I.B.M. card is even more difficult to achieve, for the same reasons. The report form proposed (Fig. 1) and the I.B.M. layout to go with it (Fig. 2) are therefore specifically designed to handle airframe defects.

To obtain defect data on the other major components of the overall weapons system which Avro will require, the other contractors will be asked to use a report form of a type similar to the Avro form, including all those items of information which are important to Weapons Systems management. Copies of all defect reports on the Weapons System will be transmitted to Avro, and separate I.B.M. layouts will be prepared to enable us to record these outside reports in the most efficient way. I.B.M. techniques are sufficiently flexible that this presents no difficulty.

This data will enable Avro to maintain a watch on all aspects of the Weapons System reliability, although it is anticipated that reliability analysis down to assemblies and parts will be conducted by Avro only on airframe systems.

3.3 The Kind of Reporting Required

The philosophy of reporting under the proposed system is that notice should be taken of every incident affecting serviceability, and that the reports be forwarded to the central processing group at Avro with the minimum of delay. Further, every report should contain complete identification of the component or part concerned, details of the environment and circumstances of failure, and how it was detected. Also required are a description of the type of trouble and possible cause, and information about the effect of the trouble on the serviceability of the Weapons System, both as regards severity and time out of service.

3.4 The New Style of Form

The type of form which is proposed to meet these considerable demands is shown in Fig. 1. It is appreciated that by comparison with present standards of reporting these requirements are searching, but it is submitted that a new standard can be attained. Several features of the new form serve towards this end:

(i) In spite of the number of questions to be answered, the form has been kept small in size.

(ii) It will be issued in check-book form, to be carried in the mechanic's or Field Representative's pocket and filled in on the job.

(iii) Check-boxes are provided where possible.

(iv) The person reporting will be expected to make full use of the back of the form to write a detailed story, using as a guide the questions on the front of the form. Narrative type reports are thus still possible, but brevity and relevance are encouraged.

(v) Our Staff Engineer Human Factors has already advised informally on the actual layout of the form. It is anticipated that several alternative arrangements might be put on trial in the Experimental Hangar. It will be very important to the success of the whole system that an attractive layout is finally offered to the Field Representatives, and many modifications are anticipated during the early development of the system.

It will be clear that the new form still calls for enthusiastic co-operation from the field force. Although the topic will not be further laboured now, it is in fact essential to the success of the system that the reporting field agents be of at least as high quality as the best Service Representative presently employed; representation of this quality has been assumed throughout, as may be seen from the details of the report form. Ways and means of improving the present service are considered later in this report.

3.5 Completing the Form

The form in Fig. 1 has been filled in with an example which makes use of almost every block of the form. The agent is reporting a case where he was able to trace the trouble to a particular part, in this instance the Manual Relief Valve of the Compensator in the Flying Control Hydraulics.

In practice the report will more often specify only the complete assembly or component. The component will usually be removed and sent to overhaul without being further dismantled. More detailed information in that case will come later from the Overhauler on a separate form. The Overhauler's information will be connected with the original Field Defect Report by means of the Report Number, which will be written on the Defective tag accompanying the component back to overhaul.

It is visualized that a report such as that in the example will actually require the attention of two people in the field to ensure its completeness. One man close to the job will record identification and immediate details while the work is going on. The second, with greater responsibility, will fill in times and any other more obscure items which may require the investigation of log books or time-sheets. He will also be required to check the whole report, since it is not intended that any more than two persons will handle the form before it is mailed to Avro. It is too early at present to be more specific about the kind of organization between Air Force mechanics and Avro Representatives which will be required in the Customer's maintenance shops.

3.6 Some Features of the Form

It will be noted that the form calls for detailed information on some aspects of the defect situation which have previously been the subject of guesswork and estimation. Emphasis is placed on the

3.6 ....cont'd

recording of component age at failure, so that meaningful defect rates in terms of hours in use can be deduced, instead of "defects per month", "defects per squadron" or other such figures which are statistically useless. (See Blocks 10 (v) and 11 (iv) on the report form.)

Blocks 12, 16 and 17 are those which give an indication of the cost of the defect, both direct and through loss of serviceability of the Weapons System. These factors alongside the actual defect rates will determine priority of action on units of poor reliability.

Blocks 16 and 17 will also help bring to light poor logistic arrangements and inefficient maintenance procedures. Block 16 is a good example of where proper understanding of the real purpose of reporting must be instilled in the Field Representatives. The final object is to assess the loss of wartime effectiveness of the Weapons System due to the fault which is being reported. Thus block 16 asks for elapsed time out of service, excluding lunch breaks, C.O.'s inspections and other interruptions which would not be allowed to hold up the aircraft in emergency.

The words for Type of Trouble and Cause of Trouble in Blocks 19 and 20 are selected as the most common from a longer list which is printed on the inside cover of the book of forms. This list will undoubtedly undergo changes during development of the system, since exact figures as to the most useful words will be obtainable mechanically from the I.B.M. cards. It will be noted that the Type/Cause words, and the check-box alternatives in other blocks are all numbered. This is part of the code which is necessary for recording the content of the Field Defect Report on an I.B.M. card.

The use of the items called for on the form is further explained in Chapter 5 of this report, and the Appendix gives working details.

3.7 The I.B.M. Card

Figure 2 illustrates the I.B.M. card on which the data of the report is punched to enable machine sorting, tabulation, and other mechanical processing. As is probably well known, the holes are punched by a machine having a key-board like a typewriter. The card has 80 columns, each of which takes either one or two punched holes according to whether a number or letter is intended. The interpretation of the punching is printed along the top of the card. The I.B.M. machines "read" the card by means of electrical contact through the punched holes.

3.8 Coding

To represent the information on the Field Defect Report by only 80 letters or numbers obviously requires considerable condensation by coding. This is carried out by one, or perhaps two, coders back at the plant, as described in a later section of the report. Examples of the code-sheets appear in the Appendix of this report.

So that machine tabulations (Fig. 3) will be at least partially intelligible to those not working daily with the codes, an effort has been made to simplify where possible within the severe limitations on space. Thus the "System Name or Structure Location" code is taken direct from the Avro Design Numbering System, and the "Assembly or Component" code is allied with the index of Maintenance Data Record (M.D.R.) sheets. As an aid to interpretation an explanation sheet will be provided with every tabulation (Fig. 4).

The card of Fig. 2 does not contain, even in code form, every piece of information which can be extracted from the report. Only data which is liable to be subject to machine processing, or essential reference data, is punched, except for some concessions to readability of the card. Thus the Manufacturer's Part Number is all that is strictly necessary to identify the part referred to in the example, and the Part Name "Manual Relief Valve" is not given in full. But the code "V1" means "Valve"; this is fairly easy to remember, and gives the layman reading the tabulation a good idea of what report number 02357 is about. It also enables the I.B.M. machinery to perform several useful accumulations automatically when statistics are called for on performance of Valves in Hydraulic Systems.

3.9 Part Cards and Component Cards

On the I.B.M. card the System, Assembly and Part are specified in turn by 3 codes. Column 19, labelled "Reference", carries the number "3", and means that this is a "Part Card" - that is, the detailed information in the 30 following columns is taken mainly from the "Part" section of the Field Defect Report. Information from the "Component" section of the Report is not punched in full on this I.B.M. card.

To record all the "Component" information a second card with "Reference" number "2" is punched, with detailed component data

3.9 ....cont'd

replacing the part data of columns 20-49. The "Component Time since Overhaul or Total Time" area of this card, which is now vacant, is used to record "Aircraft Total Hours".

Component Cards and Part Cards are stored in separate decks, so that when detailed tabulation or analysis of data on complete components is required it is not necessary to separate out the Part Cards on which component data is not given in full.

3.10 Trailer Cards

The long-hand story of the case, which the Field Representative may write on the back of the Report Form, is not suitable for coding or subject to mechanical analysis. It is therefore recorded separately. A synopsis of the story is punched letter by letter on what are known as "Trailer" cards, which are stored separately for most purposes, but are combined in the same deck with the coded cards ("Header" cards) for machine tabulations such as that in Fig. 3. When a defect investigation requires original reports in full, these can always be readily produced. Indexing and access to originals is greatly simplified by the new system.

4. THE ANALYSIS AND ACTION ORGANIZATION

4.1 Flow of Information

The personnel responsible for the operation of the proposed system can be regarded as falling into two main divisions; those concerned with completing the Field Defect Report and getting it as far as preliminary screening at Avro, and those concerned with extracting the information from the Report and acting upon it. The two divisions are equally responsible for the success or failure of the program. So that field personnel may be made fully aware of their importance in the system, and to make the system efficient in other respects, it is essential that the organization be an informational closed loop, as shown in Figure 5.

Figure 5 depicts the details of the analysis and action functions. The block at the top of the chart, where flow originates, includes all the other functions: distribution of the blank F.D.R.'s to the field, completion and checking in the field, and transmission back to Avro's Maintenance and Reliability Section. It also includes the return of summary reports and individual action reports to the separate reporting agencies, so that each will be aware of the overall defect situation and also of the action resulting from its own reports.

4.2 Getting Good Reports

It is anticipated that the new system will work under favourable conditions both in the Avro Experimental Hangar and eventually in the field, since the Arrow will have first priority among R.C.A.F. aircraft, and will not exist in great numbers until the system is well established. This should mean that the personnel working on the Arrow can be to some extent hand-picked, and this should certainly apply in the case of Avro Service Representatives. If the men responsible for the critical stage of actually tracking and reporting every defect are of good quality, and fully indoctrinated at the outset, it should be possible to maintain enthusiasm for the system.

To this end the reporting personnel must be kept fully informed and assured of the effort at other bases and back at the plant. This can be done by the circulation of summaries of the total defect picture so that each station can compare its problems with the overall situation, and by making sure that when a fix is decided upon, reporting agents are individually informed that action was taken as a result of their efforts. The field representatives should also be familiar with the plant end of the operation, both for their own information and to enable them to fill out reports effectively. Regular meetings are essential between the reporting force and the Maintenance and Reliability Engineering Section, to maintain personal interest and enable the direct discussion of matters requiring co-operation.

4.3 Engineering Function

Figure 5 illustrates the Engineering Function, which accepts the material from the Field Defect Reporting organization, uses it, and in due course acknowledges the material by reporting back results.

It is well to point out that although the proposed system is designed to make the fullest possible use of high-speed data processing methods, a fair amount of manual work is still required in feeding and programming the machines. Personnel of a different kind are required for analysis and interpretation of the raw data produced by the machines. Thirdly, liaison between Reliability Analysis and the users of the information, including Vendors, will be most effectively carried out by personal contact requiring specialised liaison personnel. These people will belong to the section labelled Reliability Engineering, which of course has other functions in the overall reliability program not shown in this flow chart.

4.4 Initial Processing

Field Defect Reports arriving daily by mail in Engineering are first screened for legibility, completeness and technical consistency by a technician of Reliability Engineering. At this stage any unusual or critical reports are picked out and copies handed direct to Reliability Engineering for immediate action by Project Management. If any reports have serious discrepancies they are held while an inquiry is sent to the field. The remainder are coded where necessary and passed to the key punch operator with all possible ambiguities removed.

A tabulation of the day's reports is immediately run off for scanning as a final check of accuracy of the punched information, and the tabulation is then passed on to the Reliability Analysis Group. The I.B.M. cards themselves and the original FDR's are then inserted in the Master File.

4.5 Reliability Analysis

With the unusual or critical reports already singled out, the Daily Tabulation will not normally give rise to any immediate action. The routine task of Reliability Analysis will be to look out for unusually high failure rates which will not always be obvious, rather than to deal with random single failures. High failure rates will only come to light on examination of failures grouped in such a way that trends stand out.

To this end, Reliability Analysis will call for various types of tabulation from the Master Punched Card File. These tabulations will list failures from as far back in time as is considered necessary, grouping and totalling so that figures can be readily compared. It is anticipated that certain types of particularly useful tabulations will be scheduled through the month, and repeated monthly as a matter of routine. Thus, perhaps, on the first of each month, Reliability analysis will ask for all failures in the previous quarter grouped by System and sub-grouped by Component code; on the eighth of each month, all failures in the previous quarter grouped by Component code and sub-grouped by Type of Trouble, and so on.

The crudest form of analysis which can be carried out on these tabulations is simply to pick out apparent trouble spots visually. It is possible to do this very readily from IBM tabulations which have been intelligently programmed. For more scientific studies, Reliability Analysis will request special tabulations and totals from the Master File, and as necessary will request time on the Engineering Division's Computing facilities. The scope of this work is described more fully in Chapter 5 of this report.

In nearly all applications, field defect statistics are of only limited value unless combined with figures on total utilization of equipment. Failure rates can only be meaningfully expressed in terms of the number of units in service out of which the failures take place, broken down by age groups. This input is shown on Figure 5. Utilization figures must be gathered initially in the Avro hangars, and will presumably be supplied later by the RCAF. The planning of this phase of the program is being initiated.

The Maintenance and Reliability Section will maintain a library of reliability records, compiled from outside sources and from our own reliability studies. The Reliability Analysis Group thus has three sources of data: tabulations and totals from the Master File, 4.5 ..../cont'd

utilization figures, and comparative data, including qualification test data, from the reliability library.

At the output end, Reliability Analysis will work through Reliability Engineering, and partly by direct contact with the more theoretical groups who are drawn into the reliability effort. (Fig. 5)

4.6 Reliability Engineering

Unusual or critical FDR's from Technical Screening, and high failure-rate figures and summaries from Reliability Analysis, are hand-carried to the appropriate Engineering Department (Fig. 5) by a liaison man of the Reliability Engineering Group. He will be responsible for getting action as soon as possible. In some cases it may be necessary for him to organize meetings between two or more of these departments to arrive at a solution of the problem. Where the trouble is the responsibility of Equipment Design, Reliability Engineering will deal direct with the Vendor in conjunction with the Procurement Department.

Reliability Engineering will also handle the presentation of suitable routine reliability information to the functions in Groups 1 and 2 of Fig. 5, and maintain general liaison with the Service Department. This will include the preparation of material for feedback to the Field Organization.

The Project Management Office will of course be responsible for issuing assignments to cover all work requested by Reliability Engineering, and will also monitor all liaison with the Service Department.

5. PHILOSOPHY AND TECHNIQUES OF ANALYSIS

5.1 Introduction

It is not proposed to alter in principle the present method of treating serious defects which require immediate engineering attention. This category contains defects which threaten the safety of the aircraft, or which cannot be remedied by normal maintenance techniques of repair or replacement.

The major portion of defects, however, are not safety items and are temporarily remedied in the field even if engineering is required. At present, engineering attention is assigned to these defects according to various rules of thumb, such as "Action is initiated after ten unscheduled removals". Under the new system it is proposed:

(a) to measure the seriousness of defect rates in their effect on the serviceability of the weapons system in terms equivalent to dollars and cents,

(b) to tackle problems in the order giving most improvement per dollar invested,

(c) using information not previously available, to approach each problem in a more scientific way.

5.2 The Relative Seriousness of Defects

Reliability is the probable chance that equipment will hold a certain level of serviceability over a period of time, under the operating conditions encountered. An interceptor weapons system is required to be serviceable when on call, and reliable for as long as possible without attention. During wartime or a time of operational readiness, it will be on call almost 24 hours a day, the only exceptions being short periods for scheduled inspection and maintenance, and for operational damage repairs and turn-around. It must be reliable as a complete weapons system up to the point of kill and, if possible, still fully serviceable after that for the next mission.

In peacetime the role may be different. It may still be on continuous call to achieve full utilization as an expensive piece of equipment, but the level of serviceability required may depend on the kind of training or practice mission to which it is assigned. Its duty will often still require full operational capability.

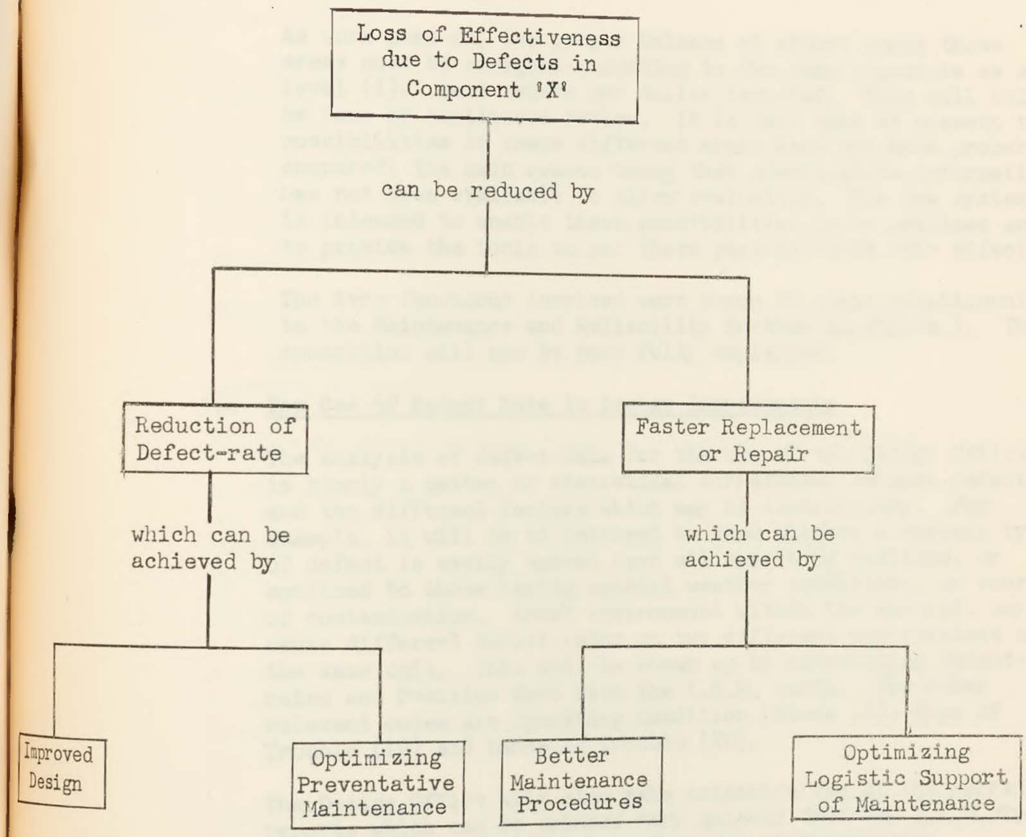

FIGURE 6 - AREAS OF EFFORT TO IMPROVE SERVICEABILITY

5.3 ..../cont'd

As work goes on, the proper balance of effort among these areas must be assigned according to the same principle as at level (i): best return per dollar invested. This will only be done by continuous review. It is felt that at present the possibilities in these different areas have not been properly compared; the main reason being that quantitative information has not been available to allow evaluation. The new system is intended to enable these possibilities to be realized and to provide the tools to put these possibilities into effect.

The Avro functions involved were shown in their relationship to the Maintenance and Reliability Section in Figure 5. The connection will now be more fully explained.

5.4 The Use of Defect Data in Design Improvements

The analysis of defect data for the use of the Design Office is simply a matter of statistical correlation between defects and the different factors which may be contributory. For example, it will be of interest to know whether a certain type of defect is evenly spread over all operating stations, or confined to those having special weather conditions, or sources of contamination. Local environment within the aircraft may cause different defect-rates on two different applications of the same unit. This will be shown up by correlating defect-rates and Position Code from the I.B.M. cards. The other relevant codes are Operating Condition (Block 13), Type of Trouble (19) and Cause of Trouble (20).

The Design Office will also make extensive use of the narrative reports which can be printed very quickly from the I.B.M. "Trailer" cards in any desired grouping for ease of examination.

5.5 Optimizing Preventative Maintenance

For all items of equipment whose life is expected to be less than that of the airframe as a whole, replacement or overhaul schedules are set up. The overhaul interval is determined initially on a basis of the expected design life of the unit and past experience on similar units. The accuracy of this estimate can only be judged when utilization figures and data on unscheduled removals have been accumulated.

5.5 ..../cont'd

Considerable research has been done on the possible ways of applying this data. (Ref. 1, 2) For example, the analyst may plot against time total hours operated by all units, divided by total of unscheduled removals occurring up to that time. When the level of this curve begins to fall, the optimum maintenance interval has been reached. If the curve is level or still rising at the end of the maintenance interval in use, the maintenance interval should be extended for optimum performance. (Ref. 1)

Maintenance schedules for all equipment in the aircraft must of course be co-ordinated, and the decision to lengthen or shorten the maintenance interval depends finally on the reduction in downtime produced.

5.6 <u>The Use of Defect Data to Improve Maintenance Procedures</u>

Maintenance instructions for all equipment in the weapons system are laid down by the Maintenance Engineering Group. The Reliability Analysis Group will supply Maintenance Engineering with figures on manhours expended per defect. These will be compared, for each type of defect, with estimated manhours, to enable evaluation of maintenance procedures.

Checking and inspection procedures will be monitored by reference to Blocks 14 and 15 of the Field Defect Report ("When was trouble detected?" and "Indication of trouble"). The rate of occurrence of aborted missions will be correlated with these items.

Maintenance Engineering will also require correlations between Maintenance Manhours and Reporting Activity (Block 5), in order to evaluate maintenance standards between stations.

5.7 <u>Optimizing Logistic Support of Maintenance</u>

Faster replacement or repair of defective units is critically dependent on the availability of spare parts and the suitability of ground support equipment, as well as on procedures. It is expected of Field Agents that they will write full reports on delays due to shortage of spares, inadequacy of ground equipment or facilities, poor instructions for trouble-shooting or maintenance, etc. Maintenance Engineering will compare these reports with reported down-time (Block 16) and maintenance manhours, and will

5.7 ..../cont'd

request further reports were discrepancies are apparent.

The problem of maintaining spare parts in stock is one which, along with optimizing maintenance intervals, has been subject to considerable operations research. Full reporting of both scheduled and unscheduled replacements will provide the necessary data for application of these techniques. Inventory problems may be tackled by use of computing facilities and Linear Programming.

5.8 The Use of Serviceability Figures in Systems Optimization

The importance of Reliability as a feature of Weapons Systems performance has already been referred to in Chapter 1 of this report. As shown in Fig. 5, there will be close liaison between Reliability Analysis and personnel responsible for overall Weapons Systems Analysis (Group 6). This will enable due attention to be given to the effect of increased serviceability on overall probability of kill, as compared with increasing the number of interceptors in readiness, or improvement in other inputs, such as radar range, speed, manoeuvrability, missile performance etc. The decision to allot funds for work on reliability will then be a matter for management, on the evidence of this analysis.

Individual systems will also be subject to analysis from the point of view of reliability when re-design of one unit may affect the reliability of other components of the system. Cases will arise where a compromise must be arranged between reliability and system performance. In these areas liaison will be required between Reliability Analysis and the Systems Analysis Section of the Technical Design Department (Group 6), and decisions will lie with the Project Designer. This will follow on from joint work already being carried out by these two Sections, as part of the overall Reliability effort.

Refs. 1. Use of Statistical Quality Control in Determining Optimum Component Time between Overhauls, Allan M. Hull, A.S.Q.C. National Convention Transactions 1956.

2. Field Data Analysis, Larmour & Neelin, C.A.I. Journal June 1956.

OPERATING DETAILS OF THE SYSTEM

A1. INTRODUCTION

This appendix amplifies the headings of some of the items on the FDR, (Fig. 1) and explains where necessary the working details of filling in the form, and coding the information. Many items are self-explanatory, and several are punched as written, or are "self-coded". On the other hand, some general remarks of explanation are required, along with the explanation of individual items.

A2. GENERAL DETAILS

A2.1 Breakdown for Identification

The breakdown is "System Name or Structure Location", "Assembly or Component", and "Part".

A good deal of confusion exists in the industry as to the meaning of the terms "Component" and "Part". The following definitions have been found to be workable:

A "Part" is an item not normally subject to further disassembly, such as a bolt, resistor, shaft, electron tube, etc.

A "Component" is a group of parts assembled to perform a function. A component is not usually capable of operating by itself. Examples are: Pump, generator, amplifier, aileron, etc.

A "System" consists of a group of components and/or parts specially integrated to perform a function or functions. All the Systems of the Arrow are enumerated in the Design Office numbering system.

The principle of punching the information of Blocks 9 thru 11 on "Part" and "Component" cards has been explained in Chapter 3. The "System", "Component" and "Part" breakdown requires two I.B.M. cards. Electronics manufacturers generally use a 4-stage breakdown. We may wish in the future to punch onto Avro I.B.M. cards electronics data received from other manufacturers; the present layout should be able to do this, by using 3 cards instead of 2.

A2.2 Part Number

The Avro Part Number is not called for on the FDR. This is because the Manufacturer's Part Number provides better identification (the same Avro Part Number may describe a part being supplied by two different manufacturers) and the Manufacturer's Part Number is more readily available to the reporting agent. There is not space on the I.B.M. card for both numbers, so a choice had to be made.

On the I.B.M. card a portion of the Avro Part Number does appear as the System Name or Structure Location code. The Reliability Group will be able to provide immediate cross-reference between Avro and Manufacturer's Part Numbers.

A2.3 Simultaneous Defects

An aircraft will often be unserviceable due to more than one defect at a time. Each defect is reported separately unless it is actually related to another, and Blocks 12, 16 and 17 require some clarification in such a case. This is an example of where reporting agents will require briefing before they begin to use the system.

These three items are to be completed as if the defect being reported had happened singly; this rule will require the agent in many cases to make an estimate. e.g. Where the removal of an access panel enables two unrelated defects to be remedied, the man-hours required should be reported as if the panel had been removed twice, and the time unserviceable is reported according to the same principle.

A3. DETAILS REGARDING INDIVIDUAL ITEMS

Item

1 Report Number (R/N) Columns 71 thru 75.

2 Related Report Number (R R/N) Column 76.

The cheque-book of Field Defect Report forms issued to the reporting agent will contain some forms with the R/N space blank, as well as printed-number forms.

In the case of a report unrelated to any other, a printed-number form is used and R R/N is filled in as zero. Where it is required to relate two or more reports, the first is written on a printed-number form, putting R R/N = 1. Related reports are written on blank-number forms, filling in the R/N from the printed form, and writing R R/N = 2, 3, 4 etc., as required.

Some such system is necessary since it may be required to reassemble related reports after they have been transcribed to I.B.M. cards and mixed in the stack. The proposed method seems to conserve report numbers and I.B.M. columns in the best way. To save writing, related reports can be stapled together by the reporter and repeated information omitted on all but the first form.

A3. DETAILS REGARDING INDIVIDUAL ITEMS .....cont'd

Item

2 Printed-number forms should not be wasted, since the quantity of forms that can be numbered in five columns is not infinite. If a printed-number form is spoiled for any reason, a blank-number form should be used, filling in the number from the discarded printed-number form.

A Report Form with the 3-stage breakdown (System, Assembly and Part) all completed will give rise to two I.B.M. cards which will bear the same R/N, but different Reference numbers. Each Related Report Form may give rise to two I.B.M. cards in the same way.

For reporting from overhaulers who may want to detail many (more than five) different parts in connection with one assembly failure, a separate Report Form will be provided, to avoid using a different piece of paper for each part. The Overhaulers' form will carry the R/N of the original F.D.R. (obtained from the tag on the component), system and component data repeated, and the part information tabulated below. All entries will give rise to separate I.B.M. cards, with R R/N's in sequence, the same R/N, and Reference number "2" (see Reference Number information in this Appendix).

It will be noticed that when R/N begins with a zero the zero does not appear in the I.B.M. print-off. This is due to a limitation of the 402 printer, and is of no consequence.

3 Reported By Not punched

It is recommended that this space be filled in by the first person to write on the F.D.R., even in cases where a Service Representative or Air Force N.C.O. checks the form and completes some portions before mailing to Avro.

When an Action Reply on the F.D.R. is returned to the base, it will be addressed to the person named in "Reported By", and can be shown by him to the more senior agent, if one is involved.

4 Date Columns 1 thru 4

This item has been partially coded to save I.B.M. columns. Month is punched as a number, with letter N = November and D = December. Only the last digit of the year is punched (e.g. 7 = 1957). This system will be acceptable for 10 years. e.g. 8 Nov. 1963 = 08N3.

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

4 As with Report Numbers, the I.B.M. 402 printer is unable to produce a zero in the first column when tabulating, but this omission is of no consequence.

5 Activity Column 5

This information is coded by means of a letter. Where one base has more than one squadron or maintenance unit, separate codes will be allotted, to enable comparison of data among all units, as well as among all geographical locations.

The tentative code at present is:-

Avro Flight Test	=	A
Avro Production	=	P
North Bay	=	N
Casey	=	Y
Val d'Or	=	V
Kapuskasing	=	K
Comox	=	O
Uplands	=	U
Bagotville	=	B
Cold Lake	=	L
Namao	=	M
Saskatoon	=	S
Chatham	=	C

6 Aircraft Type Column 63

For the Arrow a code will be set up to distinguish marks or variants where necessary.

At present 1 = Arrow 1.
2 = Arrow 2.

7 Aircraft Serial Number Columns 64 - 66

Only the last 3 digits will be punched.

8 Aircraft Total Hours Columns 41 - 44 (Component Card)

The purpose of recording aircraft total hours as well as assembly and part hours is to enable cases to be distinguished where an assembly may be wearing out sooner in a new aircraft than in an old aircraft, or vice-versa. It is therefore necessary to punch the data on component cards only.

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

9 System Name or Structure Location Columns 6 and 7

The coding of this information is based on the Avro Design Office numbering system. Although the breakdown used in the D.O. system will not be known to all field technicians, it should not be difficult to report this item with sufficient accuracy that it can be correctly understood back at the plant. Reporting on systems should be straightforward; structural defects will sometimes be more difficult to describe, but should be relatively few in number, compared with all equipment defects.

The code sheet for this item is as follows:-

Systems		Location	
11	Electrical	51	Radar Nose
12	Instruments	52	Front Fuselage
13	Electronics	53	Canopy
14	Engine Installation	54	Centre Fuselage
15	Flying Controls	55	Intakes
16	Fuel	56	Duct Bay
18	L.P. Pneumatics	57	Drop Tanks
19	Utility Hydraulics	58	Engine Bay
20	De-Icing	59	Rear Fuselage
21	Oxygen	62	Wing Inner
22	Air Conditioning	64	Wing Outer
23	Fire Protection	72	Dive Brakes
26	Armament Hydraulics	74	Aileron
28	Furnishings	82	Elevator
31	Landing Gear	83	Fin
32	Flying Control Hydraulics	84	Rudder
		91	U/C Structure - Nose
		92	U/C Structure - Main
		94	Arm. Pack - Fuselage
		95	Power Plant

10 (i) Assembly or Component Name Columns 8 thru 11

Within each system name or structure location, assemblies or components have been assigned individual code numbers. Thus under System 32, Flying Control Hydraulics -

01 = Elevator Jack and Linkage
02 = Compensator
17 = Aileron Parallel Servo
etc.

A3. DETAILS REGARDING INDIVIDUAL ITEMS ....cont'd

Item

10 (i) Where several identical components exist on the aircraft, they have the same Component Code number, and are distinguished by means of Position Code (see Block 10 (iv)); components which are handed but otherwise identical are treated in the same way, even where their Avro part numbers differ.

Changes in design, manufacturer, location, maintenance procedure, etc. for a component will give rise to alphabetical suffixes on the Component Code number. Thus the Compensator after one modification would become 02A, after a second modification 02B etc. These successive changes of the code will be agreed with the Maintenance Engineering Group; the code is in fact allied with the numbering of their Maintenance Data Record Sheets. This change of code with every modification will enable direct analysis of the effect of modifications (including re-location, change of maintenance procedure, etc.).

A portion of the Component Code for the Flying Control Hydraulics System is given below:

CODE	ITEM	AVRO PART NUMBER	MFGR'S P/N
01	Jack and Linkage, Elevator	7-3262-15 (L.H.) 7-3262-18 (R.H.)	
02	Compensator	7-3258-37	
03	Jack & Linkage, Rudder	7-3283-5	
04	Differential Servo, Rudder	7-3283-7	
05	Valve, Control, Aileron	7-3264-12	
06	Valve, Control, Rudder	7-3283-8	
07	Valve, Control, Elevator	7-3262-33	
08	Valve, Pressure Control	7-3258-14	
09	Accumulator, Self-displacing	7-3258-41	
10	Pump, Hydraulic	7-3258-13	
11	Filter, 40 gpm	7-3258-43	
12	Jack & Linkage, Aileron	7-3264-23 (L.H.) 7-3264-24 (R.H.)	
13	Switches, Pressure Warning	7-3258-35	
14	Heat Exchanger, Oil/Fuel	7-3256-5 (L.H.) 7-3256-6 (R.H.)	

A3. DETAILS REGARDING INDIVIDUAL ITEMS ....cont'd

Item

10 (iv) & 11 (iii) Position or Reference Number Columns 34 thru 40

The use of this information has already been mentioned (para. 5.4). The position of most components or parts can be described by the use of "Port" & "Starboard", "Upper" & "Lower", or combinations of these (see code below).

In the case of Electrical and Electronic equipment, where most instances of repeated application of a part are found, Design Office "E" & "R" numbers already exist. Unfortunately these "E" & "R" numbers will change with different series of aircraft in such a way that for complete identification it will sometimes be necessary to cross-refer to aircraft serial numbers.

An Electrical Reference Number such as E1066/35 (connector 35 on harness E1066) will be punched on the Part Card as "1066" in Component Position columns, & "35" in Part Position columns. The "E" is omitted since Electrical System is already identified as 11 in columns 6 and 7.

Three I.B.M. columns are assigned to "Part Position" to accommodate numbers such as E2/106.

The alphabetic Position Code given below is punched in either or both Position areas on the card. The first of the 4 spaces is not used so that the code will fit in the 3-place Part Position area of the I.B.M. card.

ALPHABETIC POSITION CODE

Port	=	--P-
Stbd	=	--S-
Upper	=	---U
Lower	=	---L
"A" System	=	---A
"B" System	=	---B
Forward	=	--F-
Aft	=	--A-
Male	=	---M
Female	=	---F
e.g. Port Upper	=	--PU

A3. DETAILS REGARDING INDIVIDUAL ITEMS ....cont'd

Item

10 (v) & 11 (iv) Hours since New or Overhaul Columns 41 thru 48

The accurate recording of equipment life is essential to almost all reliability work. The necessary sources of these figures are not at present fully provided. The possibility of time-meters on various kinds of equipment has been discussed without any definite results. Time-meters will actually be available in only a few instances, so that fairly elaborate log-keeping procedures are required to be set up.

It is anticipated that the completion of this item on the F.D.R. will be the responsibility of the more senior of the two agents who will normally be concerned with each report.

(vi) & 11 (v) Last Overhauler's Name Column 49

This item will generally be transcribed by the second agent from the equipment log at the same time as Hours since New or Overhaul.

Where the equipment is overhauled by the Manufacturer, Overhauler's Name will be coded as zero. A detailed code will be prepared for other overhaulers.

See also notes on Item 10 (vii).

(vii) & 11 (vi) Manufacturer's Name Columns 20 & 21

Manufacturer's Name and Last Overhauler's Name will be correlated with defects to enable comparisons between manufacturers and between overhaulers, on a statistical basis.

Part of the Manufacturer's Name code is given below.

A Q	Aeroquip
P M	Aircraft Porous Media
A E	Aviation Electric
A V	Avro Aircraft
B X	Bendix
D E	Dowty Equipment
E P	Eastern Aircraft Products
G A	Garrett Corporation
J H	Jarry Hydraulics
L M	H.W. Loud Machine Works
M E	Meletron Corporation

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

10 (vii) & 11 (vi)	M H	Minneapolis Honeywell
	N Y	New York Air Brake Company
	P K	Parker Appliance
	P A	Parmatic Engineering
	P D	Powerlite Devices
	P P	Prenco Progress Engineering
	R P	Railway and Power
	R E	Resistoflex Corporation
	V I	Vickers Incorporated
	V N	Vinson Manufacturing c/o Rousseau Controls

11 (i) Part Name Columns 12 thru 14

Codes are provided only for classes of parts having the same basic name; thus B09 = Bolt, and all the different shapes and sizes of bolts on the aircraft will be distinguished after coding only by their manufacturer's part number.

A portion of the code is given below:

A01	Adaptor
A02	Anchor Nut
A03	Arm
B01	Baffle
B02	Ball
B03	Bellcrank
B04	Bar
B05	Bearing
B06	Block
B07	Body
B08	Boss
B09	Bolt
B10	Bonding
B11	Bracket
B12	Button
B13	Bushing
C01	Cable
C02	Cap
C03	Casing
C04	Casting
C05	Channel
C06	Circlip
C07	Clamp
C08	Clip
C09	Collar
C10	Connection
C11	Cotter Pin
C12	Coupling
C13	Core
C14	Cover
C15	Cup
C16	Cylinder

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

12 Serviceability of Aircraft Column 56

The mission or next mission of the Weapons System will be aborted if a sufficiently serious defect is discovered after take-off or too late prior to scheduled time of readiness. The check-mark for Item 12 will therefore appear in the left or right-hand column according to when in the operational cycle the defect was detected, and how much time was required to effect the remedy.

The choice of level of serviceability to be checked, on the other hand, depends strictly on the nature of the defect. Last minute detection of a defect in the missile release mechanism might cause the aircraft to be grounded in the sense that the mission is aborted, but it is not grounded in the sense that it is unable to leave the ground. This would be a case where the correct serviceability report is #3 --- the next mission is aborted, but the aircraft is capable of performing its task as far as lock-on. "Grounded" in this item is therefore to be understood in the sense of being incapable of taking off.

Cases will arise in training and practice roles where partial loss of serviceability occurs and must be reported, but the mission is not affected because full serviceability was not required. For example, a defect of A.I. radar in an aircraft assigned to G.C.I. exercises would not abort the mission and would be correctly reported as #2 in this item.

13 Operating Condition at Time of Trouble Columns 15 & 16

This item must be distinguished from "When was trouble detected?". The source of most information will be pilots' reports, but in many cases operating condition at time of trouble will simply not be known. Reporting agents will be able to assist considerably by noting in their narrative reports any less specific information which may be relevant in this connection. Thus it may be useful to know what operating conditions the aircraft has been through since the equipment was last used or tested, even if these conditions appear to have no common factor.

The information in this item has a bearing on operating and testing procedures, as well as supplying the engineer with assistance in analysing the failure.

Erratum: Report No. 70/REL 00/1 APPENDIX

page 10 Item 12. The last sentence should read:

"For example, a defect of A.I. radar in an aircraft assigned to G.C.I. exercises would not abort the mission and would be correctly reported as #7 in this item".

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A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

12 Serviceability of Aircraft Column 56

The mission or next mission of the Weapons System will be aborted if a sufficiently serious defect is discovered after take-off or too late prior to scheduled time of readiness. The check-mark for Item 12 will therefore appear in the left or right-hand column according to when in the operational cycle the defect was detected, and how much time was required to effect the remedy.

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A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

13 The code below appears complicated because only two I.B.M. columns were available to cover all the combinations of conditions relevant to both airframe and electronic failures.

Operating Condition Code

		Col. 1	Col. 2
Unknown		U	U
Unknown, but in the air		U	A
Unknown, but on the ground		U	G
Storage	Before Installation	O	O
Handling	Before Installation	O	1
Inspection	Before Installation	O	2
Aircraft Inactive	Installed	O	3
Ground Running, Ground Functional Test	Installed	O	4
Take-off		O	5
Landing		O	6
Overshoot		O	7
Accident or Crash		O	8
Altitude up to 10,000'		1	
Altitude 10,000' to 20,000'		2	
Altitude 20,000' to 30,000'		3	
Altitude 30,000' to 40,000'		4	
Altitude 40,000' to 50,000'		5	
Altitude 50,000' to 60,000'		6	
Altitude 60,000' to 70,000'		7	
Altitude 70,000' to 80,000'		8	
Altitude 80,000' to 90,000'		9	

	failed gear switched on	failed gear switched off
Speed up to M = .75	0	5
Speed .75 to 1.25	1	6
Speed 1.25 to 1.75	2	7
Speed 1.75 to 2.25	3	8
Speed over 2.25	4	9

A3. DETAILS REGARDING INDIVIDUAL ITEMS ....cont'd

Item

14 When was Trouble Detected? Column 17

The code for this item is given below:

Turn around	=	0
1st Line Maintenance	=	1
2nd Line Maintenance	=	2
3rd Line Maintenance	=	3
Daily Inspection	=	4
25 hour Inspection	=	5
50 hour Inspection	=	6
100 hour Inspection	=	7
Special Inspection	=	8
Pre-flight Inspection or Functional Check	=	9
In Normal Flight	=	A
* Air Test	=	B
Non-routine Test Flight	=	C
As in "Operating Condition" (normal)	=	D
As in "Operating Condition" (air test)	=	E
As in "Operating Condition" (non-routine)	=	F

* "Air Test" includes all routine flight tests made after inspection, maintenance, or modification, and also production flight tests. "Non-routine Test Flight" includes all experimental test flying.

15 Indication of Trouble Column 18

Almost all defects are discovered on account of their effect rather than by direct observation of the defect itself; in other words "Type of Trouble" and "Indication of Trouble" are usually different. The record of Indication will be most useful in cases where units are replaced as unserviceable without the reporting agent knowing what the type or cause of trouble is. This item will also be valuable as a check on inspection procedures and the adequacy of warning systems.

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

15 The code is as follows:

Flight Characteristics	=	A
Improper Operation	=	B
Inoperative	=	C
Intermittent	=	D
Low Performance	=	E
Leaking	=	F
Noisy	=	G
Off Frequency	=	H
Out of Adjustment	=	I
Overheating	=	J
Smoking	=	K
Unstable	=	L
Vibrating	=	M
Warning Light	=	N
Other	=	O
Visual Examination	=	P

The code "Other" will probably be frequently used, and the reported indication spelled out on a trailer card. More words can be added to this code list if considered useful.

16 Time Aircraft was Unserviceable due to this Defect Columns 57 thru 59

17 Man-Hours Expended to Remedy this Defect Columns 60 thru 62

These two items should be the responsibility of the more senior reporting agent. The use of the information is explained in Chapter 5, and the matter of simultaneous defects is discussed in paragraph A2.3. It has also been pointed out earlier that these items must be completed with the purpose of the report in mind - time or man-hours expended due to practices which would not occur in the operational situation are not to be reported.

19 Type of Trouble Columns 50 & 51

20 Cause of Trouble Columns 52 & 53

Wherever possible the reporting agent should try to express this part of his report by means of the listed words. Given a completely free hand, agents reporting two similar defects

A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Item

20 can easily make it appear that the defects are different by their choice of phraseology. Having checked the words nearest what he wants, the agent can then expand in his narrative report, and any need for modifications of the printed list will soon become evident. The agent should always be careful to distinguish Indication, Type, and Cause, which are not always easy to separate.

The complete list of words is given below. The words given on the F.D.R. are marked with an asterisk; the others are listed on the inside cover of the book of F.D.R.'s.

01	Arcing	33	Handling
02	Alignment	34	Gain High/Low
03	Accum. Tolerance	35	High Current
04	Binding	36	Inadequate/Improper Info.
* 05	Broken	37	Part Incorrect/Missing
06	Burned	38	Improper Wiring
07	Brinelled	39	Improper Use
08	Cracked	40	Interference
09	Chafing	41	Intermittent
* 10	Corrosion	42	Jammed
11	Calibration	43	Jitter
12	Contacts Trouble	* 44	Loose
13	Containers/Packaging	* 45	Leaking
14	Contamination	* 46	Lubrication
15	Crash	47	Machining
16	Distorted/Bent	* 48	Maintenance
17	Design	49	Marking Improper
18	Deterioration	50	Material Defective
19	Excessive Load	* 51	Mislocated
* 20	Excessive Moisture	52	Open Circuit
21	Excessive Pressure	53	Out of Adj/Tolerance
22	Excessive Voltage	* 54	Overheating
23	Fatigue	55	Overhaul Replacement
24	Finish	56	Oscillation
25	Forming	57	Oversize
* 26	Foreign-Matter	58	Peeling
27	Fouling	59	Rigging
28	Frayed	60	Riveting
29	Frozen	* 61	Short Circuit
30	Galled/Scored/Fretting	62	Slipping
31	Grounded	63	Storage
32	Handbook (Tech)	64	Shipping

A3. DETAILS REGARDING INDIVIDUAL ITEMS .....cont'd

Item

20

65 Solder/Weld/Brazing
* 66 Seized
67 Shock
68 Sticky
69 Temp High/Low
70 Torn/Cut/Punctured
* 71 Torquing, Over/Under
72 Undersize
* 73 Unknown
74 Unbalanced
* 75 Vibration
76 Weak
77 Worn

Reference Number Column 19

Reference Number distinguishes "Part" and "Component" I.B.M. cards. "Part" cards have Ref. No. "3" and "Component" cards have Ref. No. "2".

On a "Part" card the detailed information punched in the 30 columns following "Reference Number" is taken from the "Part" section of the F.D.R. On a "Component" card these 30 columns are punched with information from the "Component" section of the F.D.R., i.e. "Part Manufacturer's Name" and "Manufacturer's Part Number" will be replaced by "Component Manufacturer's Name" and "Manufacturer's Number of Component" respectively, "Component T.S.O. or Total Time" will be punched in the columns at present labelled "Part T.S.O. or Total Time", and the "Component T.S.O. or Total Time" columns will be used to punch "Aircraft Total Hours" from the F.D.R.

Component and Part cards will be stored in separate decks and normally subject to separate analysis. They will be of different colour, and if necessary Component cards with corrected column headings can be prepared to facilitate reading of the punched information directly from the card. Punched information will normally be read from a print-off, however, and the I.B.M. card column labels are simply for the convenience of the I.B.M. operators.

Entry Status Column 54

This item indicates the source and reliability of the report as punched. The code is:

Agent's guess	= 1	Air Force investigation	= 3
Agent certain	= 2	Overhauler's investigation	= 4.

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A3. DETAILS REGARDING INDIVIDUAL ITEMS ......cont'd

Entry Status

There is no space devoted to this item on the F.D.R. Codes 1 & 2 are distinguished by reference to the field agent's narrative remarks. Codes 3 & 4 will arise in cases where the original F.D.R. has been followed up later by a more detailed report. The original I.B.M. card will then be removed and replaced by a card with entry status and any other items revised as necessary according to the detailed report.

Action Code Column 77

I.B.M. cards will remain in the master file for statistical purposes during the time engineering is taking action, and also after the case has been closed. Action Code will enable the status of each defect report to be distinguished, and will provide a simple means of monitoring progress in dealing with reports.

The code is as follows:

First Punching	Statistics only	= 0
	Critical	= 1
	Normal	= 2
Re-punched after action	Mfg. procedure changed	= 3
	Redesigned	= 4
	Specification rewritten	= 5
	Maintenance procedure changed	= 6
	Maintenance schedule changed	= 7
	Instructions rewritten	= 8
	Air Force responsibility	= 9

Summary Number Columns 78 & 79

These two columns of the I.B.M. card have been set aside for use by the I.B.M. machine programmers in organizing tabulations.

Card Code Column 80

No narrative on F.D.R.	= 0
Header card	= 1
First Trailer Card	= 2
Second Trailer Card	= 3
etc.	