Aerospace Medical Research Laboratories

A FACTOR ANALYSIS OF SELECTED HOW-MAL CODES

WILLIAM H. PEARSON

Distribution of this document is unlimited

FOREWORD

This study was initiated by the Systems Research Branch, Human Engineering Division, Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories. The work was performed between January 1966 and May 1966 in support of Project 7184, "Human Performance in Advanced Systems", Task 718403, "Man-Machine Systems Research". Mr. William H. Pearson was the principal investigator. Dr. Donald A. Topmiller was task scientist.

The author wishes to thank Dr. Donald Topmiller for the idea leading to this research and his critical reading and helpful suggestions. The author wishes to thank MSGT John Hyson of the Aeronautical Systems Division, Mr. E. Balsey of the Air Force Logistics Command, and Mr. N. Rountree of Kelley Air Force Base, San Antonio, Texas, for their invaluable help in providing the data to make this investigation possible. The appearance and readability of this report owe much to the expert typing by Miss Jean Pyles, Systems Research Branch, and the editing by Mr. G. Ronnie Taylor, Technical Editing Branch. The author wishes to thank other members of Systems Research Branch and Dr. Melvin Warrick, Human Engineering Division, for their critical reading and helpful suggestions.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory
Aerospace Medical Research Laboratories

ABSTRACT

This report concerns the possibility of simplifying the Air Force's list of malfunction data-reporting codes (How-Mal Codes) given in AFM 66-1. Two complementary methods of approaching the problem, through analysis of the codes as reported, are illustrated using maintenance data from the T-37 aircraft. One analytical method involves a straightforward tabulation of the frequency-of-use of the various code words. The other method involves a mathematical technique (factor analysis) for identifying the basic "factors" underlying the maintenance man's categorizations of malfunctions. Of 150 How-Mal code words, 43 accounted for 99% of the reports of malfunction tabulated on 180 mechanical components of the T-37 System. Ninety-five percent of the 62,387 malfunctions analyzed were accounted for by only 20 code words. The factor analysis suggests that as few as 16 code words may be sufficient to describe the 43 more common malfunctions. Further analyses are required, using these and other techniques and other systems, before specific recommendations can be made for simplifying the code through combining, reorganizing, or grouping code words.

SECTION I

INTRODUCTION

One of the world's largest data management systems is that which reports maintenance data and activity under the provisions of AFM 66-1 (ref 2). Some one million Hollerith cards describing malfunctions and maintenance data on Air Force weapon systems, e.g., C131, F104, T39, etc., are punched each week. The information recorded on each maintenance action includes: the nature of the malfunction, the type of system, the type of repair action, etc.

This study is concerned only with malfunction data. Under the provisions of AFM 66-1, the nature of the malfunction is indicated by one of approximately 150 How-Malfunction (How-Mal) codes. A How-Mal code is a 3-digit code number plus one or more descriptive code words. Some examples are: 008-Noisy; 020-Worn, Frayed, or Cut. A How-Mal code is intended to describe only how a component malfunctioned; it does not give the cause for a malfunction.

The set of How-Mal codes may possibly be simplified by eliminating all but the really useful ones. This study will illustrate two methods for determining the usefulness of a How-Mal code. One method involves mathematically determining similar code words; the other method involves ascertaining which How-Mal codes are actually used most frequently.

That How-Mal code words, as used, are related among themselves might be expected. The definitions of many code words appear, on a common-sense basis, quite similar. Examples are 116-Cut and 540-Punctured; 381-Leaking and 410-Lack of/Improper Lubrication. Furthermore, some of the subtle differences among code words are of little if any practical importance. For example, scratched, marred, and scarred may be separate and distinct conditions but the maintenance technician need not discriminate among them because, in all cases, his action is the same--replace the component, if necessary.

This report describes an attempt to find groups of How-Mal codes whose code words are for the maintenance technician maximally discriminable from other groups of code words but are not significantly different from one another. It is hoped that each group of homogeneous code words can be replaced by either a new code word which represents the general meaning of the group or one of the existing code words which best exemplifies the group. It is felt that if there were fewer codes the appropriate code would be easier to find, fewer errors would result, and less time would be required to fill out forms.

In a reporting system of the magnitude of that regulated by AFM 66-1 the potential savings resulting from only a small improvement may be tremendous. If each mechanic saves only 5 seconds filling out a form a savings of 1400 man-hours per week over the one million forms per week would result.

As a further product of this study, one may obtain estimates of the frequency of the use of each of the How-Mal codes investigated and each of the artificial groups of homogeneous code words which appear to be similar in meaning. One might suspect that some of the code numbers are used quite frequently and others infrequently. Several explanations for this might be advanced: personal bias of the maintenance man, differential frequencies of various similar types of malfunctions, which code he finds first in a list, etc. This report will also examine frequency of use of a How-Mal code number as another indicator of its utility.

SECTION II

METHOD

The method of factor analysis was used to isolate the groups of similar How-Mal code words. Not all 150 codes were investigated in this study but only the 43 more frequently used codes, those dealing primarily with mechanical malfunctions. Of the How-Mal codes dealing with mechanical malfunctions, only 43 appear more than five times in the reporting document cited below. These codes and their intercorrelations appear in Appendix I.

The T37 aircraft was selected as the system whose data would be used in this analysis. The data used are contained in the D 056-B11 Report for January 1965 to June 1965 and were obtained from the San Antonio Air Material Area (AMA), the AMA responsible for logistic management of this aircraft.

Four items of information were used from the D 056-B11 Report: (1) the type of aircraft, (2) the type of repair action, (3) the How-Mal code number, and (4) the subassembly on which the repairman worked. Each of these items of information is given for all maintenance actions in the USAF. There is at least one maintenance action for every malfunction.

Every component or subassembly of this system has an identifying 5-digit alphanumeric symbol called a Work Unit Code (WUC). These are given in Technical Order 1T-37B-06 (ref 4). In this report only WUC's for which 100 or more malfunctions were reported are used. Only WUC's with more than 100 maintenance actions yield a sufficient number of How-Mal code numbers to be useful in the factor analysis described later. No miscellaneous or "Not Otherwise Classified" WUC's were used.

There are also many types of repair for which codes are given in AFM 66-1. These codes are called Action Taken Codes (ATC). A list of these is given in reference 4 and also in AFM 66-1 (ref 2). Seven of these were used in this analysis. Only eight ATC are used in the D 056-B11 report; one appears only infrequently. The seven used in this analysis are: (1) F. Repair, (2) G. Repair and/or Replacement of Minor Parts, Hardware and Softgoods (Seals, Gaskets, Electrical Connections, Fittings, Tubing Hose, Wiring, Fasteners, Vibration Isolators, Brackets, etc.), (3) K. Calibrated - Adjustment Required, (4) L.

Adjustment, (5) P. Removed, (6) R. Remove and Replace, and (7) Z. Corrosion Treatment, includes Cleaning, Treating, Priming, and Painting of Corroded Items. Malfunction frequencies for codes K and L were grouped together as were frequencies for ATC codes P and R and for F and Z. This grouping was made to increase frequencies within a cell of the data table.

The intercorrelations among the 43 How-Mal codes were computed over the 180 WUC's by 4 ATC's. The frequency of each How-Mal code number in each WUC by ATC group constituted a score. Each correlation was then based on an N of 720. Restriction of range caused by the low frequency of occurrence of some How-Mal codes reduces some correlations to 0.0. Any non-zero correlations with these infrequent codes are undoubtedly the result of chance and should be considered unstable.

The matrix of intercorrelations, with 1.0 in the diagonal cells, was factor analyzed by the use of the BIMD 17 (ref 1), a principal-axis-type factor solution (ref 3), which yields independent factors. The number of factors chosen was equal to the number of eigenvalues greater than 1.0, where the eigenvalue is a measure of the strength of a factor. Factor strength is also an indicator of how many codes are related to that factor. The obtained factor structure was rotated through 12 iteration cycles by a Varimax method. The BIMD 17 program (ref 1) also yields the mean frequency of occurrence of each of the How-Mal codes which were used in the secondary analysis.

SECTION III

RESULTS

The factor analysis technique disclosed that the 43 How-Mal codes fell into sixteen independent groups (factors) accounting for 65.6% of the variance. Table I[1] gives the codes and their frequencies, factor loadings, and communalities. The factors, the How-Mal codes belonging to each factor, and the factor loadings of each How-Mal code on its factor are given in Table II. Two codes, 037-Fluctuates, Unstable and 135-Binding, Stuck were very poorly described by the data and fell into no category. The residual tables are given in Appendix I.

Not all the How-Mal codes appear equally frequently. In fact, the 43 How-Mal codes chosen for the report account for at least 99% of all the How-Mal codes used in the D 056-B11 Report. Moreover, these 43 are not used equally often, either. Twenty of the 43 account for roughly 95% of the 62,387 frequencies of the 43 How-Mal codes used in the present study.

---

1. See tables at end of report.

Table III gives the cumulative percent of the frequency of How-Mal codes accounted for by various numbers of How-Mal codes ranked by frequency. The Spearman rho between the frequency of use of a code number in this sample and its ordinal position in a list of the codes ordered by code number is 0.444, $p < .01$. The Spearman rho between the frequency of use of a code number and its ordinal position in a list where the code word is alphabetically ordered is 0.25, $p > .05$. The Spearman rho between the total frequency of use of all codes belonging to a factor and the ordinal position of the eigenvalue in a list ordered by eigenvalue, i.e., the strength of that factor, is 0.82, $p < .01$.

SECTION IV

DISCUSSION

Some psychological or descriptive significance may be ascribed to the groups of codes which make up a factor. The codes which make up a factor are mathematically determined, but the psychological or descriptive significance attached to the factor is at the discretion of the analyst. These factors describe the technician's interpretation of the appearance or action of the malfunctioning aircraft, not the cause of the malfunction.

The first factor is conceptualized as one describing a situation in which components of the vehicle have come off or are about to come off. Missing or damaged fasteners suggest this. The presence of cracks or lost parts bears it out.

The second factor is conceptualized as one describing a situation in which the vehicle has broken, bent, or buckled parts as a result of heating or collision with a blunt object.

The third factor describes an unexplained failure of some subsystem.

The fourth factor describes a clean break or near break in some part or between two parts. A cut or a puncture is obviously of this nature. This interpretation is rendered more likely when one looks at the raw data. The code 540 Punctured occurs describing malfunctions of seals, gaskets, fittings, tubing, etc., and of the wing tips, main tire, flap assembly, and speed brake assembly which could be of a cuts-due-to-wear variety typical of this factor.

The fifth factor describes light surface damage.

Factor VI appears to describe wear over or in a large general area. This wear sometimes results in tears or loss of parts.

Factor VII appears to describe a situation in which a moving part is noisy or unadjustable because of lack of oil or hydraulic fluid. Malfunctions described by this factor occur in the canopy actuator, aileron assembly, rudder assembly, rudder tab actuating mechanism, rear bearing assembly, and powerplant.

Factor VIII is a poor maintenance factor. It is exemplified by lack of attention to loose parts and fittings.

Factor IX describes a situation in which some attention has been paid to maintenance but it has been sloppily done. Factor IX is defined as the Improper Adjustment factor.

One might suspect that the presence of low-frequency How-Mal codes would invalidate the factor analysis. If a code is used so seldom, it may represent an error or an idiosyncratic use of a code. For this reason only the 20 codes representing 95.1% of the frequency were reanalyzed. Essentially the same factor structure as for all 43 codes appeared. Eight factors were extracted, former factors I, II, III, VI, and X repeating. These are given in Appendix II. Former factor IV did not repeat because only code 020-Worn was present. Former factors VIII, XII, & XIII were all mixed together in one factor, as were two more previous factors, on both new factors VII and VIII. The presence of the extra low-frequency codes served merely to clarify the factor structure of the codes by helping to isolate each pure factor.

Factor X and the following ones are difficult to interpret. A possible exception is factor XIV which pertains primarily to tires and has to do with shimmying and oscillating. This relationship between codes 910-Chipped and 458-Out of Balance is based on a correlation of 0.0. This is a logical inconsistency, however, This factor shares a common trouble with factors X through XVI; it has only a mathematical existence and probably will not appear in any future studies.

A similar analysis should be replicated several times on several aircraft before the factors obtained can be considered reliable. Plans are underway to replicate the above analysis on at least the T29, T38, F106, C131, and B58G. It is expected that future replications of the analyses will probably support the final factor structure of the analysis of 20 codes rather than the sixteen factors found in the initial analysis. This is believed to be the case because factors X to XVI apparently have only a shakey mathematical existence.

One can see from examining Table III that some code numbers are used quite often but others are used much less often. The explanation for this is not quite clear. The most obvious is that not all malfunctions are equally probable. This viewpoint, while undoubtedly true, cannot explain why frequency of malfunction and value of the code number are significantly correlated. It has been suggested that each repairman has pet codes which he uses frequently. Since not everyone would have the same pet code this state of affairs might lead to a more or less equal distribution of code number frequencies.

The pet-code hypothesis, while probably true, is still apparently not the whole answer. It has been suggested that the repairman searches through his list and records the first applicable code number he locates. This would explain the significant correlation between frequency and numerical value of code number. The Technical Order manuals, however, have lists with the code numbers in both numerical order and alphabetical order. The correlation between frequency of use of How-Mal code number and position in the alphabetical list is not significant. Why would the repairman tend to use one list and not the other?

An expert on How-Mal codes (MSGT John P. Hyson) of the Technical Requirements Office, Aeronautical Systems Division, has informed the author that the codes with the lower numbers are more general, pertain to a wider scope of situations on the average, than codes with higher numbers. The more general codes would apply to a wider range of malfunctions and thus have the higher frequencies of occurrence. Generality of code would lead to a correlation between code number and frequency.

As noted previously the correlation between frequency of use of a code number and the ordinal position of the factor to which it belongs is insignificant but the correlation between the frequency with which all the codes in a factor are used and the ordinal position of the factor is significant. Apparently the malfunctions which occur most frequently are associated with the strongest and best defined factors. The notion that some codes are more general than others would explain these results, too. The codes with more generality would be more likely to be associated with other codes. Since the strength of a factor is a measure of how many codes it is associated with as well as the constituent variable loadings, the stronger factors would tend to have the higher frequencies of occurrence of their associated codes. Therefore, strength and frequency should be correlated.

SECTION V

CONCLUSIONS

It was concluded that significantly fewer than the current 150 How-Mal codes might describe the set of malfunctions quite well and that they could be found by the methods described in this report. Fewer than 150 How-Mal codes may describe malfunctions quite well. Twenty of the 43 codes used accounted for 95% of the data. Add to this the fact that some of the codes are related and one might conclude that perhaps only 50 to 75 of the 150 How-Mal codes are really necessary to describe malfunctions adequately. The results of this study are believed to be sufficient to establish the method. Varying the equipment class, weapon system type, and method of analysis (i.e., multidimensional scaling study also) should establish a more discriminable set of code dimensions for maintenance data reporting technology.

TABLES I, II, III

TABLE I

THE HOW-MAL CODES, THEIR FACTOR LOADINGS, AND THEIR COMMUNALITIES

HOW-MAL CODE	DESCRIPTOR ST'M'T	I	II	III	IV	V	VI
008	Noisy	09	-02	11	03	-02	-01
020	Worn, Chafed, or Frayed	-03	00	00	-97	-01	01
037	Fluctuates, Unstable	01	01	30	01	-02	-05
070	Broken	10	-85	02	00	-01	-12
105	Loose/Damaged Fastener	86	00	-04	-04	-04	-07
106	Missing Fastener	56	-04	-02	-04	-01	-20
108	Broken Safety Wire	-04	-02	01	01	01	-07
116	Cut	-04	00	00	-98	-01	01
117	Deteriorated	-02	-03	-01	-02	04	-87
127	Adjustment Improper	02	00	-03	-01	00	00
135	Binding, Stuck or Jammed	-03	-01	11	01	02	01
170	Corroded	13	01	-01	02	-02	-13
190	Cracked	52	-12	-04	-04	-02	-11
230	Dirty, Contaminated	00	-02	-03	-02	01	01
242	Fail to Operate	-01	01	93	01	-01	02
246	Improper Maintenance	07	00	09	-06	-01	06
301	Foreign Object Damage	-02	-95	00	01	-01	01
374	Internal Failure	-03	00	88	00	-01	00
381	Leaking	05	-02	-03	-06	-03	01
386	Lost in Flight	69	02	01	00	12	07
410	Lack of Lubrication	-04	-01	-08	02	-01	05
518	Improper Routing	-02	01	-04	00	00	02
553	Does not meet specs	-01	-07	02	-02	05	-05
561	Unable to Adjust	-01	00	23	02	03	-06
585	Sheared	19	-01	10	02	-04	04
599	Travel Incorrect	-06	-02	01	-01	-01	04
602	Fail Due to other Fail	-10	-01	09	-09	06	01
605	Crazed	04	01	-02	-01	90	-05
660	Stripped	12	00	-05	02	01	-02
719	Broken Ground Wire	-04	00	-03	-02	-01	-01
730	Loose	16	01	-04	03	-03	-01
750	Missing	21	-03	-02	-02	02	-39
780	Bent, Buckled, Collapsed	02	-90	-02	00	00	00
846	Delaminated	17	-02	01	01	-01	-04
878	Weather Damage	03	00	00	00	00	-06
901	Intermittent	-01	-02	83	00	00	00
910	Chipped	-02	01	-02	-09	-01	-04
932	Does Not Lock	-11	-03	-02	00	03	07
935	Scored, Scratched	02	01	00	01	91	01
947	Torn	08	-03	00	-02	-01	-86
458	Out of Balance	-10	01	-04	-25	-02	-02
540	Punctured	15	00	-01	-89	01	-07
900	Burned	-04	-95	02	00	-01	02

NOTE: Decimal points have been omitted. Underlined numbers represent significant loadings on that factor.

VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	h^2
-60	06	-02	30	-13	-04	03	09	00	-22	56
-02	01	01	01	00	00	03	-07	01	-03	95
-38	-08	00	-09	-04	02	-10	-01	-06	-35	39
02	14	00	03	-06	30	06	-01	-02	-01	86
-01	07	-02	08	-04	12	03	05	00	05	78
02	24	-03	17	-05	48	19	-03	02	-09	73
04	73	-08	-07	-09	03	11	-05	01	-07	59
-01	01	00	02	00	-02	01	-08	00	-02	96
02	01	-04	05	-03	-07	06	05	10	-03	78
-03	00	80	-01	-01	02	-02	-01	-01	03	64
-36	-07	36	-08	-03	09	12	02	01	11	32
12	-06	-03	49	06	-14	37	08	03	-22	52
-07	05	04	33	-03	33	-12	08	-05	25	61
-09	-03	00	04	-04	03	-09	-04	-02	-62	42
-12	02	00	01	-14	-02	00	00	-01	-03	90
-05	53	-06	02	03	07	44	00	09	05	51
-07	-02	00	-01	00	-07	-01	-01	00	-02	91
-29	01	-01	02	-06	00	-02	-01	-01	-07	86
-63	12	-10	-08	-06	-01	-05	04	03	-06	50
-05	-06	-04	-08	-10	-20	-03	-04	03	-11	58
-53	-07	07	03	05	-08	31	-06	01	19	50
04	29	07	01	02	-03	-12	08	50	-27	43
-18	13	00	-06	-77	03	07	-03	-02	-06	67
-49	-07	06	06	06	06	-08	-01	01	-06	33
11	-08	03	11	-73	-02	02	05	03	-01	62
05	00	77	01	00	-06	-01	00	03	-07	62
-16	02	-04	66	-18	-03	-20	-19	-04	21	64
02	-01	-01	00	-01	02	02	01	-01	-04	82
-01	02	00	78	05	14	03	04	-02	-07	66
-04	05	02	-04	-08	01	71	00	-05	13	54
-08	57	16	18	-05	02	-24	02	-09	25	55
07	28	-03	16	-03	42	40	-01	-05	-08	65
01	-03	01	01	-01	02	-03	02	-01	01	82
04	-07	01	11	11	76	03	-09	-02	-06	65
-06	-13	-02	-05	-01	04	04	-05	86	17	80
10	02	02	-01	06	-02	02	01	00	09	71
-07	-06	-03	00	-11	04	-06	86	-02	13	80
-05	06	-01	-08	-08	56	-05	10	04	03	36
00	00	00	04	01	00	-04	-01	01	03	83
-05	02	-01	00	02	07	-05	-01	-05	04	77
-03	-04	-05	07	-25	03	-12	-44	-04	20	40
01	-01	03	-01	-01	01	02	16	-01	02	85
01	-03	01	00	-02	-07	00	-01	01	00	92

Sum Equals 28.22

TABLE II

CODES DESCRIBING VARIOUS FACTORS & THEIR LOADING

FACTOR	CODE	DESCRIPTOR	LOADING
FACTOR I	105	Loose/damaged fastener	.86
	386	Lost in Flight	.69
	*106	Missing Fasteners	.56
	190	Cracked	.52
FACTOR II	301	Foreign object damage	-.95
	900	Burned	-.95
	780	Bent, buckled, collapsed	-.90
	070	Broken	-.85
FACTOR III	242	Failed to Operate	.93
	374	Internal Failure	.88
	901	Intermittent	.83
FACTOR IV	116	Cut	-.98
	020	Worn, chafed, or frayed	-.97
	540	Punctured	-.89
FACTOR V	935	Scored, scratched	.91
	605	Crazed	.90
FACTOR VI	117	Deteriorated	-.87
	947	Torn	-.86
	750	Missing	-.39
FACTOR VII	381	Leaking	-.63
	008	Noisy	-.60
	410	Lack of Lubrication	-.53
	561	Unable to Adjust	-.49
FACTOR VIII	108	Broken safety wire	.73
	730	Loose	.57
	*246	Improper Maintenance	.53
FACTOR IX	127	Adjustment improper	.80
	599	Travel Incorrect	.77
FACTOR X	660	Stripped	.78
	602	Failed due to other failure	.66
	170	Corroded	.49
FACTOR XI	553	Does not meet specs	-.77
	585	Sheared	-.73
FACTOR XII	846	Delaminated	.76
	932	Does not lock	.56
	*106	Missing Fastener	.48
	*750	Missing	.42
FACTOR XIII	719	Broken ground wire	.71
	*246	Improper maintenance	.44
	*750	Missing	.40
FACTOR XIV	910	Chipped	.86
	458	Out of balance	-.44
FACTOR XV	878	Weather damage	.86
	518	Improper routing	.50
FACTOR XVI	230	Dirty, contaminated	-.62

* Indicates factorially complex code.

TABLE III

CUMULATIVE FREQUENCY AND PERCENT OF FREQUENCY ACCOUNTED FOR BY VARIOUS NUMBERS OF HOW-MAL CODES RANKED BY FREQUENCY

	HOW-MAL CODE	DESCRIPTOR	FREQUENCY	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
1.	020	Worn	10,750	10,750	17.2
2.	190	Cracked	8,127	18,877	30.3
3.	105	Loose Fastener	6,204	25,081	40.2
4.	381	Leaking	4,526	29,607	47.5
5.	127	Adjustment Improper	4,224	33,831	54.2
6.	070	Broken	3,475	37,306	59.8
7.	374	Internal Failure	3,445	40,751	65.3
8.	780	Bent	2,903	43,654	70.0
9.	117	Deteriorated	2,305	45,959	73.7
10.	730	Loose	2,148	48,107	77.1
11.	242	Failed to Operate	1,795	49,902	80.0
12.	170	Corroded	1,648	51,550	82.6
13.	108	Broken Safety Wire	1,587	53,137	85.2
14.	660	Stripped	1,578	54,715	87.7
15.	037	Fluctuates	959	55,674	89.2
16.	750	Missing	942	56,616	90.7
17.	106	Missing Fastener	817	57,433	92.1
18.	947	Torn	730	58,163	93.2
19.	719	Broken Ground Wire	653	58,816	94.3
20.	230	Dirty	504	59,320	95.1
21.	135	Binding	484	59,804	95.9
22.	900	Burned	413	60,217	96.5
23.	116	Cut	340	60,557	97.1
24.	246	Improper Maintenance	295	60,852	97.5
25.	935	Scored	186	61,038	97.8
26.	901	Intermittent	155	61,193	98.1
27.	518	Improper Routing	147	61,340	98.3
28.	910	Chipped	130	61,470	98.5
29.	008	Noisy	126	61,596	98.7
30.	458	Out of Balance	122	61,718	98.9
31.	585	Sheared	105	61,823	99.1
32.	301	Foreign Object Damage	88	61,911	99.2
33.	553	Not Meet Specs	85	61,996	99.4
34.	561	Unable to Adjust	74	62,070	99.5
35.	605	Crazed	68	62,138	99.6
36.	932	Does Not Lock	55	62,193	99.7
37.	602	Failed, Other Failure	53	62,246	99.8
38.	599	Travel Incorrect	34	62,280	99.8
39.	540	Punctured	31	62,311	99.9
40.	878	Weather Damage	27	62,348	99.9
41.	410	Improper Lubrication	27	62,375	99.9
42.	386	Lost in Flight	6	62,381	99.9
43.	846	Delaminated	6	62,387	100.0

THE VARIABLES, THEIR INTERCORRELATIONS, AND THE MATRIX OF RESIDUAL CORRELATIONS AFTER EXTRACTION OF THE FACTORS

VARIABLE NUMBER		VERBAL DESCRIPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	008	Noisy	44	00	19	03	07	15	-01	00	00	00	10	09	06	07	22	02	07	27	29	07	19	01
2	020	Worn, Chafed, or Frayed	-01	05	-01	01	00	03	00	99	01	-01	00	-01	01	01	00	06	00	01	06	00	00	00
3	037	Fluctuates Unstable	-12	01	61	00	-03	-02	-01	-01	01	01	07	-02	-03	08	27	-04	02	40	10	07	07	-01
4	070	Broken	00	01	01	14	14	27	15	00	10	00	02	01	24	03	02	10	74	02	01	00	-01	00
5	105	Loose/Damaged Fastener	-03	-01	00	00	22	57	01	-01	06	01	00	11	49	-01	-04	12	-01	-04	07	39	-02	-01
6	106	Missing Fastener	03	00	-01	-04	-02	27	25	02	16	01	00	15	41	-01	-04	23	-02	-04	05	17	-02	03
7	108	Broken Safety Wire	-03	00	04	01	00	04	41	00	09	-03	-01	00	-03	-01	01	25	-01	-01	02	-02	-02	06
8	116	Cut	-03	04	00	01	-01	00	00	04	00	-01	-01	-01	-01	02	-01	05	00	00	05	00	-01	00
9	117	Deteriorated	-03	00	-01	-01	02	00	00	00	22	-03	-01	20	09	00	-03	03	-01	-02	01	00	-03	02
10	127	Adjustment Improper	01	-02	01	00	00	02	04	-02	00	35	15	-03	06	-01	-01	-01	-01	-02	-03	-02	06	01
11	135	Binding, Stuck, or Jammed	-06	00	-06	00	02	01	06	00	02	-15	68	-02	00	00	10	02	01	17	09	00	12	00
12	170	Corroded	-06	01	02	00	-02	-03	03	01	02	02	07	48	11	-01	-03	08	-01	-03	-03	03	00	-01
13	190	Cracked	-06	-01	04	-03	-06	-09	00	00	03	-01	-04	02	39	-01	-04	05	05	-04	04	12	-02	-02
14	230	Dirty, Contaminated	-13	-03	-17	00	02	06	-02	-02	00	00	05	-11	10	58	04	-02	04	04	06	04	02	01
15	242	Failed to Operate	-13	00	-07	01	00	01	-02	00	-01	01	-04	-01	00	03	10	08	01	88	10	02	02	-02
16	246	Improper Maintenance	-06	-02	03	-02	00	-04	-18	-02	04	04	-01	-04	01	06	-01	49	-02	09	06	01	06	05
17	301	Foreign Object Damage	01	00	00	-04	01	00	-01	00	-04	-01	-02	01	-03	00	01	00	09	02	08	01	02	-01
18	374	Internal Failure	-03	00	00	01	02	-01	-02	00	-01	00	-02	01	00	-01	02	01	00	14	16	03	04	-02
19	381	Leaking	-13	00	-15	-01	02	01	-05	-01	02	03	-08	09	-01	-03	04	-02	02	00	55	02	13	01
20	386	Lost in Flight	-03	02	00	03	-15	-09	05	02	05	01	04	-04	-12	-03	00	02	02	01	-06	42	-01	-01
21	410	Lack of Lubrication	-07	00	-01	02	02	04	05	00	01	-01	-14	-02	-02	11	00	-06	01	02	-16	01	55	00
22	518	Improper Routing	-03	-01	-04	00	01	-02	-15	-01	-02	-04	05	-02	06	-14	01	-08	00	01	-02	-02	11	57
23	553	Does not Meet Spec	00	-01	-03	-02	02	00	-06	-02	00	-01	-03	06	06	-05	-04	01	-08	-03	-06	00	-02	-01
24	561	Unable to Adjust	-09	00	-08	01	00	-02	06	01	-03	-02	-06	05	02	-04	-06	03	03	-04	-15	00	04	00
25	585	Sheared	-01	04	-01	-01	-04	03	00	03	01	-03	02	00	-02	-02	-01	04	-01	-02	04	-10	09	00
26	599	Travel Incorrect	02	-03	-01	-02	06	05	03	-03	02	-26	15	-02	01	-05	-01	03	00	-01	10	04	-01	00
27	602	Failed Due to Other Fail	-16	-01	05	02	01	-01	06	-02	-01	03	01	-08	-01	10	-01	02	02	02	01	11	00	05
28	605	Crazed	02	00	01	00	-01	01	03	00	-03	00	-02	01	-01	-01	01	-01	00	02	02	-07	01	01
29	660	Stripped	00	01	03	01	00	-01	02	01	01	00	06	-22	-10	-06	01	00	02	00	02	02	03	-03
30	719	Broken Ground Wire	-02	-01	09	-02	01	-04	-05	-01	00	-01	10	-17	05	12	-01	-15	-01	00	02	05	-17	02
31	730	Loose	01	03	07	-01	-08	-04	-18	03	00	-07	00	10	-03	12	01	08	01	00	-08	-04	02	-07
32	750	Missing	02	-03	00	-01	-04	-05	-03	-02	-04	02	00	-05	00	-03	-01	-12	00	00	00	00	-02	00
33	780	Bent, Buckled, Collapsed	00	00	00	00	01	-01	00	00	-02	-01	-01	01	00	00	00	01	-08	01	-01	01	-01	01
34	846	Delaminated	02	-01	-02	-01	-10	-03	03	02	00	-01	-03	01	-05	-07	02	01	03	00	04	05	07	05
35	878	Weather Damage	02	00	07	00	-04	00	08	00	-03	01	-06	01	00	11	00	-02	-07	00	-04	-04	-07	-31
36	901	Intermittent	05	00	-11	00	02	01	00	00	-01	00	-02	-01	00	09	-06	-08	00	-13	08	01	08	04
37	910	Chipped	-04	-03	03	00	-03	04	08	-02	-02	02	-03	01	-06	09	00	04	02	01	-05	04	03	-01
38	932	Does Not Lock	00	01	-03	01	05	-10	-04	01	08	00	-04	16	-05	-01	00	02	00	00	-01	16	02	-03
39	935	Scored, Scratched	01	02	02	01	00	-02	-02	02	-01	00	-01	01	00	01	01	00	02	00	02	-04	-01	01
40	947	Torn	02	-01	-06	-03	02	03	-03	-01	-12	-01	00	-07	-03	02	00	08	-01	01	-01	02	04	05
41	458	Out of Balance	03	-09	04	-01	08	04	00	-07	-01	02	00	11	-03	07	00	05	02	01	-01	05	04	10
42	540	Punctured	00	-06	00	01	00	-04	01	-06	-04	00	-01	-02	00	01	00	-02	01	01	-03	-02	04	-01
43	900	Burned	00	00	00	-04	02	01	-01	00	-03	-01	-01	00	-02	01	00	01	04	00	01	02	01	01

VARIABLE NUMBER	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1	21	24	08	-01	09	-01	26	-02	09	08	01	-01	-01	05	05	-01	-01	06	-01	-01	01
2	02	01	01	-01	09	00	00	03	00	00	01	02	00	-01	00	01	00	00	18	79	00
3	09	21	00	-01	04	-01	-02	-02	-02	-03	-01	-01	-01	06	02	-01	00	00	-01	-02	00
4	12	01	05	-03	02	00	09	03	07	29	77	25	-01	02	00	16	-01	13	-01	04	74
5	05	-02	15	-02	-03	-01	18	01	11	26	03	13	-01	-02	02	03	-01	16	01	17	-01
6	10	-02	16	-04	-01	05	28	08	15	53	03	44	02	-03	00	09	-02	27	01	10	-01
7	12	-02	-01	-03	02	-02	-01	06	15	25	-01	-01	00	02	-01	02	-01	03	-01	-01	-01
8	01	00	00	-01	09	00	-01	01	00	-01	00	00	00	-01	00	00	00	00	21	79	00
9	07	00	00	-03	00	05	06	05	01	30	00	02	10	-01	05	00	02	62	-01	04	-01
10	00	04	00	35	01	-01	-01	00	08	00	01	02	-01	-01	-01	01	00	00	00	03	-01
11	06	14	01	10	01	-02	-01	02	02	00	00	01	00	05	02	04	00	01	-01	-01	00
12	-02	00	06	-02	07	02	20	02	02	20	00	02	00	-02	01	00	-01	01	-01	00	00
13	08	07	11	-03	22	-01	25	04	26	29	13	29	00	-03	07	08	01	16	00	13	05
14	02	04	01	-01	04	02	01	-02	-02	-01	02	-01	00	-01	00	-01	01	01	00	01	03
15	12	20	17	-01	12	-01	-03	-03	-02	-03	-02	-01	-01	68	00	00	-01	-01	-01	-02	02
16	09	00	00	-03	-03	-02	07	18	13	22	-02	05	02	00	-01	07	-01	03	-01	04	-01
17	03	03	-01	-01	01	-01	-01	-01	-02	-02	78	00	00	01	00	00	-01	00	01	-01	95
18	09	30	07	-02	16	-02	-03	-03	-02	-04	00	-01	00	56	01	01	-01	00	00	-01	02
19	12	13	00	00	06	-02	-03	01	01	-02	00	-01	00	-02	02	04	-01	03	01	03	00
20	07	01	10	01	02	06	01	-02	-01	00	00	00	-01	-01	-01	-01	08	00	-01	06	00
21	03	06	-01	01	08	-01	-02	09	01	-03	-01	00	01	-01	02	-01	-01	01	-01	-01	00
22	00	-01	-01	01	-01	-01	00	00	02	01	-01	-01	02	-01	-01	-01	00	00	-01	-01	-01
23	33	04	29	-02	07	05	-01	08	04	13	04	-01	-01	00	02	02	01	02	10	03	03
24	01	67	00	01	11	00	-02	-02	-01	-01	-01	-01	01	10	01	01	03	02	-01	-01	02
25	-24	07	38	-01	12	-01	05	01	03	02	00	00	-01	00	01	00	01	01	00	01	03
26	00	-02	-04	38	-02	-01	02	01	05	-04	-02	-01	00	00	-01	00	00	-02	-01	-01	-01
27	-05	-02	-04	01	36	-01	31	-02	06	00	02	-01	-01	03	01	02	07	02	13	06	03
28	00	-02	01	01	-04	18	02	-01	-02	04	00	00	00	-01	00	01	65	02	-01	05	00
29	06	-06	-01	03	-15	00	34	-01	10	20	03	15	-01	-02	04	03	01	08	-01	02	-01
30	-04	04	-03	02	09	-01	01	46	00	24	-01	-01	01	-01	01	-01	-01	02	-01	01	-01
31	04	-03	02	-04	-14	02	-07	11	45	13	00	06	-01	-01	-01	04	-02	03	-01	00	-02
32	03	04	03	02	02	-02	-05	-04	01	35	02	28	00	-02	-01	11	-01	30	-02	12	-01
33	-02	02	-02	-04	00	02	02	01	01	-01	28	02	-01	00	01	05	00	01	-01	01	76
34	06	-05	04	04	-01	-02	-07	-01	06	-10	-01	35	00	-01	00	10	00	10	00	-01	00
35	01	-02	-04	02	02	00	05	00	11	04	00	-02	20	00	00	00	00	-01	00	00	00
36	05	-03	-05	-02	03	01	03	00	00	00	-01	00	-01	29	-01	00	00	-01	-01	-01	02
37	-04	00	-10	03	10	00	02	02	-03	-01	-01	07	02	01	20	01	00	01	00	17	00
38	-07	-03	-01	04	05	-02	02	00	01	-06	02	-26	-04	03	-11	64	01	01	-01	-01	00
39	-02	-01	03	01	-02	-17	-03	02	-02	-01	01	00	-01	00	02	-02	17	-01	-01	-01	00
40	-02	-07	06	03	01	-01	04	03	-03	-06	-02	00	-03	00	-03	04	00	23	00	08	00
41	-09	00	-14	04	-15	02	-01	01	-04	02	-01	-01	-03	04	27	-01	00	-04	60	12	-01
42	00	01	-02	-03	03	03	02	-01	01	04	00	-01	01	-01	-05	-01	-01	-01	-03	15	-01
43	-05	02	01	-04	02	02	01	-01	02	01	-10	03	-01	-02	01	01	02	00	-01	00	08

NOTE: Original Correlation Matrix above diagonal and Residual Correlations diagonal and below. Decimal points have been omitted.

APPENDIX II

LOADING OF VARIOUS HOW-MAL CODES ON DERIVED FACTORS USING ONLY TWENTY HIGH FREQUENCY HOW-MAL CODES

	HOW-MAL CODE	DESCRIPTOR	I	II	III	IV	V	VI	VII	VIII
1.	020	Worn, Chafed, or Frayed	08	-03	00	00	12	-15	-58	12
2.	037	Fluctuates	00	56	01	-04	00	-04	04	16
3.	070	Broken	20	02	-92	-09	-17	02	-03	01
4.	105	Loose Fasteners	79	-03	-01	-05	03	07	-10	05
5.	106	Missing Fasteners	70	-02	-07	-18	-34	18	-14	02
6.	108	Broken Safety Wire	-03	00	-04	-02	-86	-05	02	10
7.	117	Deteriorated	00	-01	-01	-87	-06	13	01	00
8.	127	Improper Adjustment	20	01	02	-03	07	-42	18	-45
9.	170	Corroded	14	-01	03	-09	01	71	04	-04
10.	190	Cracked	77	-02	-14	-04	05	03	02	-07
11.	230	Dirty	-01	04	-02	00	-03	01	12	69
12.	242	Failed to Operate	-04	92	-01	03	-01	02	00	-06
13.	374	Internal Failure	-03	95	-01	02	02	00	-02	-01
14.	381	Leaking	19	20	05	-02	04	-28	-32	47
15.	660	Stripped	41	-01	-02	03	05	49	16	02
16.	719	Broken Ground Wire	-01	-03	00	01	-29	13	-63	-31
17.	730	Loose	42	-01	04	07	-40	-23	34	-09
18.	750	Missing	38	-02	-10	-33	-49	29	-20	-13
19.	780	Bent, Buckled	00	-01	-94	04	08	-03	02	01
20.	947	Torn	15	02	-02	-87	00	-07	01	01

NOTE: Decimal points have been omitted.

REFERENCES

1. BIMD Computer Program Manual, Division of Biostatistics, Department of Preventive Medicine and Public Health, School of Medicine, University of California, Los Angeles, December 1, 1961.

2. Depot, Field, and Organizational Maintenance. Maintenance Management, Department of the Air Force Manual 66-1, December 1, 1964.

3. Harman, Harry H. Modern Factor Analysis. Chicago: University of Chicago Press, 1960.

4. Aircraft Work Unit Code Manual. USAF Series T-37. Technical Order 1T-37B-06. San Antonio Air Material Area, Kelley AFB, December 1, 1964.

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Aerospace Medical Research Laboratories Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

A Factor Analysis of Selected How-Mal Codes.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

PEARSON, WILLIAM H.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1966	15	4

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 7184 c. Task Nos. 718403 d.	9a. ORIGINATOR'S REPORT NUMBER(S) AMRL-TR-66-154 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Aerospace Medical Research Laboratories Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio

13. ABSTRACT

This report concerns the possibility of simplifying the Air Force's list of malfunction data-reporting codes (How-Mal Codes) given in AFM 66-1. Two complementary methods of approaching the problem, through analysis of the codes as reported, are illustrated using maintenance data from the T-37 aircraft. One analytical method involves a straightforward tabulation of the frequency-of-use of the various code words. The other method involves a mathematical technique (factor analysis) for identifying the basic "factors" underlying the maintenance man's categorizations of malfunctions. Of 150 How-Mal code words, 43 accounted for 99% of the reports of malfunction tabulated on 180 mechanical components of the T-37 System. Ninety-five percent of the 62,387 malfunctions analyzed were accounted for by only 20 code words. The factor analysis suggests that as few as 16 code words may be sufficient to describe the 43 more common malfunctions. Further analyses are required, using these and other techniques and other systems, before specific recommendations can be made for simplifying the code through combining, reorganizing or grouping code words.

DD FORM 1 JAN 64 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Factor Analysis How-Mal Codes Aircraft Maintenance Maintenance Management						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ______."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ______."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ______."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Security Classification