RL-TR-91-402
Final Technical Report
December 1991

MISSION/MAINTENANCE/ CYCLING EFFECTS ON RELIABILITY

Westinghouse Electric Corporation

F.M. Krantz and M.W. Richter

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1991	Final Sep 86 - Nov 87

4. TITLE AND SUBTITLE
MISSION/MAINTENANCE/CYCLING EFFECTS ON RELIABILITY

5. FUNDING NUMBERS
C - F30602-86-C-0080
PE - 62702F
PR - 2338
TA - 02
WU - 2N

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Rome Laboratory (ERSR)
Griffiss AFB NY 13441-5700

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
RL-TR-91-402

11. SUPPLEMENTARY NOTES
Rome Laboratory Project Engineer: Roy F. Stratton/ERSR/(315) 330-4205

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
This effort examined the effect of cycling and mission length on the mean-time-between- failures (MTBF), cannot duplicate (CND), and induced failures. No correlation was found for CND or induced failures. For almost all of the equipment examined, the failure rate increased as the cycling rate increased. A composite curve was developed for six pieces of equipment on a single type of airframe having a range of missions of different lengths. The equation for the composite curve is given in the executive summary.

14. SUBJECT TERMS
Reliability, Cycling Effects, Mean-Time-Between-Failures (MTBF)

15. NUMBER OF PAGES
72

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

EXECUTIVE SUMMARY

The objective of this study was to provide an improved and more accurate equipment and system reliability prediction methodology for equipment subject to periodic on/off cycling. Periodic operation, performance and readiness checks, and non-corrective readiness checks were considered in the analysis.

An individual engaged in equipment or system design or applications of system or equipment usage will find the results of this report useful when reliability assessments for equipments subject to cyclic periods of operation are required. The generalized algorithm and plots, with suitable caution, may be considered applicable to all avionic equipment and systems.

Findings

1. Of the equipment and systems evaluated in this study, those that exhibited the greatest reliability, i.e., lowest failure rate, usually had the longest energized cycle time.

2. Data covering a two-year period, for most of the equipment examined, shows a relationship between on/off cycling and failure rate; as the cycling rate increased, there was a corresponding increase in failure rate. The findings support the premise that equipment and system failure rate versus energized cycle time can be represented mathematically.

3. Since the mission times for most aircraft in the U.S. Air Force (this study considered only avionics) range from just under one hour to approximately 9 hours, it was not possible to evaluate and compare the results with equipment/systems in continuous operation. For purposes of this study, for a given piece of equipment, the longest mission time on an aircraft of a given type was associated with a computed energized inherent equipment/system failure rate, λ_L. Correspondingly, the shorter mission time(s) on an aircraft of that same type was associated with a total computed inherent equipment/system failure rate, λ_S. Close examination of the data revealed

that the shorter mission time aircraft experienced a higher failure rate than the longer mission time aircraft. By its nature, the shorter mission time aircraft experienced higher "on-off" cycle rates over a given total period of operating time than the long mission time aircraft did over a similar total period of operating time. The long mission time aircraft can be considered as a baseline approximating continuous operation. However, the reliability of equipment which operate for very long periods would be expected to be even higher than the reliability of equipment on 10 hour flight missions. If the data of any single mission is compared to the longest mission of that equipment, a dimensionless parameter $K_{S/L}$ can be defined:

$$K_{S/L} = \frac{\lambda_S}{\lambda_L}$$

which indicates the relative proportion of increase in failure rate between the two cycling rates (mission times).

where:

λ_S = the total inherent equipment/system failure rate associated with <u>short</u> mission time aircraft

λ_L = the energized inherent equipment/system failure rate associated with the <u>longest</u> mission time aircraft

When $K_{S/L}$ is plotted against mission time (T), a relationship can be defined by a general equation. Several general equations were considered including multi-term series expressions. However, a single term equation

$$K_{S/L} = \frac{C}{T^a}$$

provided a suitable fit for the data and was simple and easy to evaluate. When evaluating specifically for the data surveyed in this study:

$$K_{S/L} \cong \frac{3.63}{T^{0.479}}$$

where 1 < T < 10 based on the data observed

The parameter $K_{S/L}$ can be used as an adjustment to MIL-HDBK-217 reliability predictions when the anticipated mission time is known:

$$\textbf{Expected Equipment Failure Rate} = \lambda_{217} \times K_{S/L}$$

$$\textbf{Expected Equipment MTBF} = \frac{MTBF_{217}}{K_{S/L}}$$

Conclusions:

Conclusions reached from this study are:

1. Usually, the higher the "on-off" cycling rate, the higher the failure rates will be experienced.

2. The algorithms developed by this study can be used in conjunction with MIL-HDBK-217 for adjustment of reliability predictions of avionics equipment if the user is conscious of the limitation of data and the lack of environmental information in the operations. For short mission applications in particular, a higher failure rate prediction will be realized than if MIL-HDBK-217 was used alone.

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1.0 INTRODUCTION

1.1 Scope and Objective of the Report

This report presents the results of an investigation conducted by the Westinghouse Integrated Logistics Support Divisions for the Rome Air Development Center, Griffiss Air Force Base, New York, concerning the effects of on/off cycling on the reliability of avionics systems and equipment. The objective of the study was to provide an improved and more accurate equipment/systems reliability prediction methodology for equipment/systems subject to periodic on/off cycling. Periodic operation, performance and readiness checks, and non-corrective readiness checks were considered in the analysis. Several different equipment/systems, each installed on various versions of the same aircraft platforms but having different mission time cycles, were analyzed in this report.

1.2 Organization of the Report

The report is organized to serve two *types of readers*; the designer and operations personnel. The designer will be helped by having available an algorithm that accounts for on/off cycling when predicting failure rates of new equipment. The operations people will be helped by having a simple and convenient algorithm (or graphical plot) to aid in establishing policy for energizing equipment.

2.0 BACKGROUND

2.1 Historical Background

Traditional electronic reliability models or concepts relate failure rate to environmental stresses and continuous operational time. This assumes that the impact of mission cycles and on and off cycles for performance checks and maintenance actions are negligible. The problem of on/off cycling of electronic equipment and its impact on reliability has been a subject of argument and conjecture for over thirty years and has been the subject of a number of studies since the nineteen forties. Earlier studies were concerned with electron tube equipment but later efforts addressed solid state devices.(3) More recent studies have concentrated on the fracturing of internal connections in transistors and ICs resulting from on/off cycling.(7) An associated problem related to cycling has been power transistor chip cracks and failures of the mounting interface.(7)

There is a common thread that runs through many of the earlier studies: the lack of sufficient data.

2.2 Analysis of the Cycling Problem

In an effort to relate mathematically the impact of on/off cycling of avionic equipment/systems to reliability, a careful review of cycling and mission duration data was made.

The mission time for most aircraft in the U.S. Air Force range from just under one hour to approximately 10 hours. Therefore, it is not possible to evaluate equipment/systems in continuous operation. For purposes of this study, for given equipment, the longest mission time(s) on an aircraft were associated with a computed energized inherent equipment/system failure rate (λ_L) and the shorter mission time on an aircraft with a computed inherent equipment/system failure rate (λ_S). Close examination of the data revealed that the equipment on the shorter mission time aircraft experienced a higher failure rate than the same equipment on the longer mission time aircraft. The shorter mission time aircraft experiences a higher "on-off" cycle rate while the long mission aircraft have a lower "on-off" cycle rate. The long mission time aircraft can be considered as an approximation to the continuous operation condition for installed avionics equipment/systems. If the data of any single mission is compared to the longest mission of that equipment, a dimensionless parameter $K_{S/L}$ can be defined:

$$K_{S/L} = \frac{\lambda_S}{\lambda_L}$$

which indicates the relative proportion increase in failure rate between the two cycling rates (mission times)

where:

λ_S = the total inherent equipment/system failure rate associated with short mission time aircraft.

λ_L = the energized inherent equipment/system failure rate associated with the longest mission time aircraft.

It will later be shown how this parameter in conjunction with MIL-HDBK-217 can be used as a factor in reliability predictions.

2.3 Data

The data for this study is in two forms; qualitative and quantitative. The qualitative data was gathered by visiting several Air Force bases and discussing the cycling issue with maintenance personnel and unit commanders responsible for the maintenance of airborne avionics equipment/systems. The quantitative data for the study was obtained primarily from the Air Force "Maintenance and Operational Data Access System" (MODAS) and other Air Force files.[15]

3.0 DESCRIPTION OF THE STUDY

3.1 Qualitative Data

In order to gain some insight into the extent of equipment cycling under operational conditions, it was decided to visit various air bases and conduct discussions with operations personnel.

The discussions at various bases revealed some general policies or operating procedures for energizing electronic equipment. Generally, it was stated that equipment is turned on at the beginning of a mission and turned off at the end of a mission. The previous mission generally served as the check for the next mission.

During maintenance of equipment, it was pointed out that it is sometimes necessary to turn the equipment on and off a number of times to effect a repair. There was, however, no data recorded on these "on/off" cycles. It might be safe to assume that a repair process would require at least three such cycles. Some cycle failure calculations were made on this assumption, but their effect was found to be trivial compared to the cycling of operational usage.

Attempts were also made to isolate other conditions that might impact cycling failures. Through questions and discussions, it was determined that "Induced Failures" and "Cannot Duplicate (CND) Failures" as well as repair policies all have some impact on the cycling experience of the equipment. In addition, assurance was received through interviews that the number of cycles from such effects was small compared to the cycling experience from the normal operation of the equipment.

As a highly subjective (but perhaps significant) element of data, approximately one hundred experienced maintenance persons were asked if they could, out of their experience, say that cycling appreciably affected equipment failure rate. Almost every person said that out of their experience, the effect of cycling was very real and significant.

3.2 Aircraft Platform Selection

The aircraft platforms selected for this study were required to have a minimum of two platform usage scenarios which have different mission duration/cycle profiles. The various usage scenario configurations of the basic platforms were required to have some of the same equipment and systems installed.

After a careful review of our military aircraft, three separate airframes were selected for analysis. Each airframe had several different configurations that flew different mission scenarios and a variety of mission lengths. Each airframe had several pieces of avionics equipment which were installed on all of its various configurations. Comparing the same equipment installed on the same type airframe, but on different configurations of that airframe which were flying different lengths of mission, provided the best means for comparing long and short mission effects under the most similar condition of environment.

The avionic equipment/systems selected for this study are common to several aircraft platforms and represent different kinds of equipment and different complexities.

A tabulation of the types of equipment used on different configurations of type "A" aircraft platform is shown below:

Avionics:

- I Radar Beacon
- II Doppler Radar
- III Flight Director System
- IV Autopilot
- V Tacan
- VI Compass System

A tabulation of the types of equipment used on different configurations of the second type aircraft, aircraft B, is shown below:

Avionics:

VII	Tacan
VIII	Radio
IX	Transponder
X	Flight Director Computer
XI	VHF-AM/FM Radio
XII	Altitude Encoder

A tabulation of the types of equipment used on different configurations of the third type aircraft, aircraft C, is shown below:

Avionics:

XIII	Flight Control System
XIV	UHF Radio
XV	IFF Transponder
XVI	Stall Inhibitor System
XVII	Flight Data Recorder
XVIII	Radar Altimeter

4.0 DATA ANALYSIS AND REDUCTION

4.1 Evaluation Methods

When reviewing the data for the various systems in the study, it becomes apparent that the number of sorties was very large compared to the number of failures. Field visits to the various Air Force bases revealed that, for the most part, equipment/systems are turned on at the beginning of a mission and turned off at the end of a mission. Therefore, each sortie represents one "on/off" cycle. Several on/off cycles are probably required for each repair operation, but operational cycling is so large compared to repair cycling it was not included in the analysis.

The numerical data used in this report came from the MODAS system and consisted, for a given specific type of aircraft and a given aircraft configuration, of the number of sorties flown, the total number of flying hours, and the number of failures experienced during the period of interest. From the tables, it can be seen that there is wide variation in both the number of sorties and the number of flying hours. Type 1 failures are inherent failures defined as "manifested evidence of impaired operation which requires maintenance action to restore". Type 1 failures do not include "can not duplicate faults", maintenance induced faults or routine adjustments. Only Type 1 failures are given in the tables. The average mission time was taken as the total flying hours divided by the number of sorties, and the failure rates were the number of flying hours divided by the number of failures of the appropriate type. Clearly, these numbers are averages subject to considerable statistical variation. In making the calculation, one would like to have the failure rate for each piece of equipment operating continuously, the inherent failures rate, to use as a basis. Since this is not available, the inherent failure rate was approximated to be the same as the failure rate for the longest mission. Then the $K_{S/L}$ is defined as the ratio of the failure rates for a shorter mission to that for the longest mission. Graphs of $K_{S/L}$ vs mission length are given. Since all of the data for each airframe is from the same type of aircraft, it was assumed that the environmental conditions were the same, but since we do not know the actual bases, the actual environment was not known.

4.2 Summary of Data by Equipment Type

Tables 1-21, titled "Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$", show a tabulation and summation of the mission time (T), sorties, flying hours, number of Type 1 failures, and the cycling adjustment factor ($K_{S/L}$) for each system/equipment in the study. Type 1 failures are defined as "manifested evidence of impaired operation which requires maintenance action to restore". Type 1 failures do not include "can not duplicate faults"; maintenance induced faults or routine adjustments. In these tables, the mission time (T) is stated in hours and the cycling adjustment factor ($K_{S/L}$) is dimensionless.

In each case the energized failure rate λ_L was the failure rate of the system/equipment experiencing the longest standard mission time of that equipment and type aircraft. $K_{S/L}$ is the ratio of the failure rate of the equipment whose mission time is under consideration to the failure rate of the same equipment in the same platform with the longest mission time.

The data shown in Tables 1-6 are plotted in Figures 1-6 and are titled "Plot of Various Mission Lengths vs. Their Relative Equipment Failure Rates". The curves shown in these plots are derived from a least squares regression of the data points on log-log axes.[14]

The data shown in Tables 7, 14, and 21 are composites of cycling failure data of a variety of equipment used on a single type aircraft. Tables 7, 14, and 21 correspond to aircraft types A, B, and C. These data are plotted in Figures 7, 9, and 11 titled "Plot of Various Mission Lengths vs. Their Relative Failure Rates For a Composite of Avionic Equipment Types On a Single Airframe".

The data and plots for the B and C type airframes were not used in the development of a generalized algorithm because the mission times were not sufficiently spread for the purposes of this study. They are shown in Figures 9 and 11 for reference only.

The data in Table 7 is a combination of the data obtained from the six different pieces of equipment which are utilized in various versions of the Type A aircraft. The data of all six systems were tabulated in order of mission time. The objective in the review of the combined data was to provide input from each system without excess influence by a particular system. Because of the differences in the equipment in addition to the variation for a given piece of equipment, one observes a wide statistical variation in values of $K_{S/L}$.

Environmental stress correction factors, which are related to defined environments are not applicable in this case. Some of the very high values of $K_{S/L}$ were eliminated from the composite data on the assumption that they contain exceptional environmental stress components. In some cases, points which were at nearly the same mission time, were grouped by averaging the value of $K_{S/L}$. Because of the presence of undefined variation in environmental stress and variation in vulnerability of equipment to these stresses, the lower values of $K_{S/L}$ were assumed to more nearly represent the effects of cycling on equipment under normal condition of environment.

The composite curve should be recognized as a generalized view of a trend in many kinds of equipment probably exposed to different environmental stress in different locations in the aircraft and subjected to different kinds of usage stress. The application of the composite curve correction factor should be applied with the knowledge that it is the result of a combination of data from this combination of systems. For these reasons, the curve was then chosen to follow the more conservative path of the data.

Since the A type airframe provides the best data for this study, it is used to develop the generalized algorithm. The plots for each equipment/system used in the study on the type A airframe are shown in Figures 1-6 titled "Plot of Various Mission Lengths vs. Their Relative Equipment Failure Rates". These plots may be used directly when estimating the impact of cycling on similar equipment.

For systems dissimilar to those used in the study, the analyst should use the composite plot which was formed from data of systems used on Type A airframe as shown in Figure 7.

The $K_{S/L}$ from the plots or the generalized algorithm may be used in conjunction with MIL-HDBK-217 when predicting the reliability of a new equipment/system or a new application for an older system. There is reason to believe that MIL-HDBK-217 contains minimum cycling as the following expression assumes.

$$\textbf{Expected Equipment Failure Rate} = \lambda_{217} \times K_{S/L}$$

or

$$\textbf{Expected Equipment MTBF} = \frac{MTBF_{217}}{K_{S/L}}$$

Airframe Type A

Table 1. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment I (Radar Beacon)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A-2	3.16	30,196	95,293	238	5.35
A-3	3.95	44,796	177,427	467	5.50
A-4	4.49	754	3,376	11	6.67
A-5	5.06	654	3,311	4	2.91
A-7	7.65	315	2,406	1	0.91
A-9	9.97	1,301	12,967	6	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type A   Equipment I (Radar Beacon)

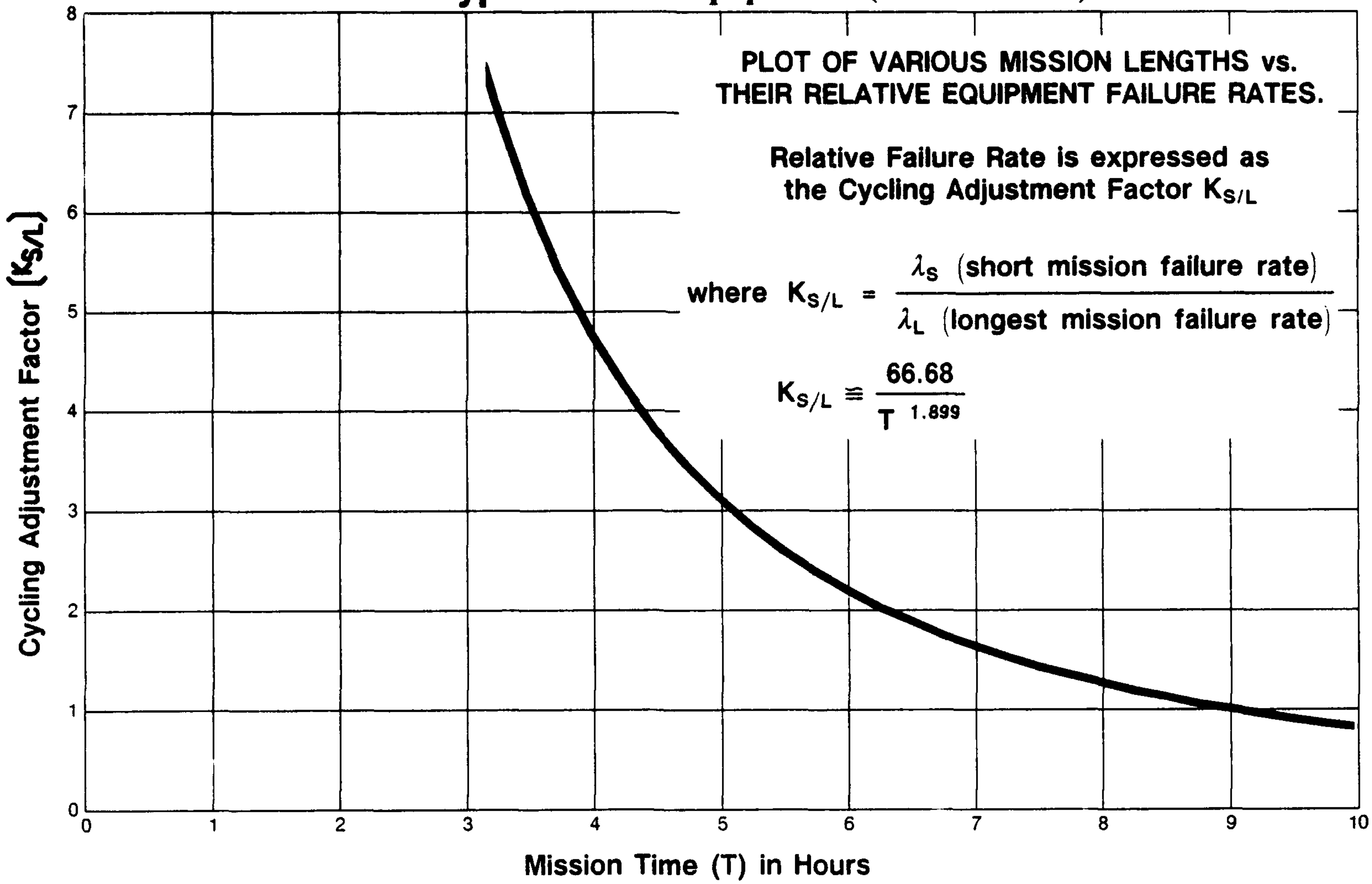


Figure 1

Airframe Type A

Table 2. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment II (Doppler Radar)

Aircraft Configu- ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A-1	2.20	946	2,082	21	5.69
A-2	3.16	29,652	93,575	282	1.88
A-3	3.94	43,507	172,319	1,126	3.50
A-4	4.49	754	3,376	12	2.09
A-5	5.03	632	3,180	17	3.24
A-6	5.46	3,663	20,008	68	1.85
A-7	7.65	315	2,406	4	0.83
A-9	9.97	1,301	12,967	23	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

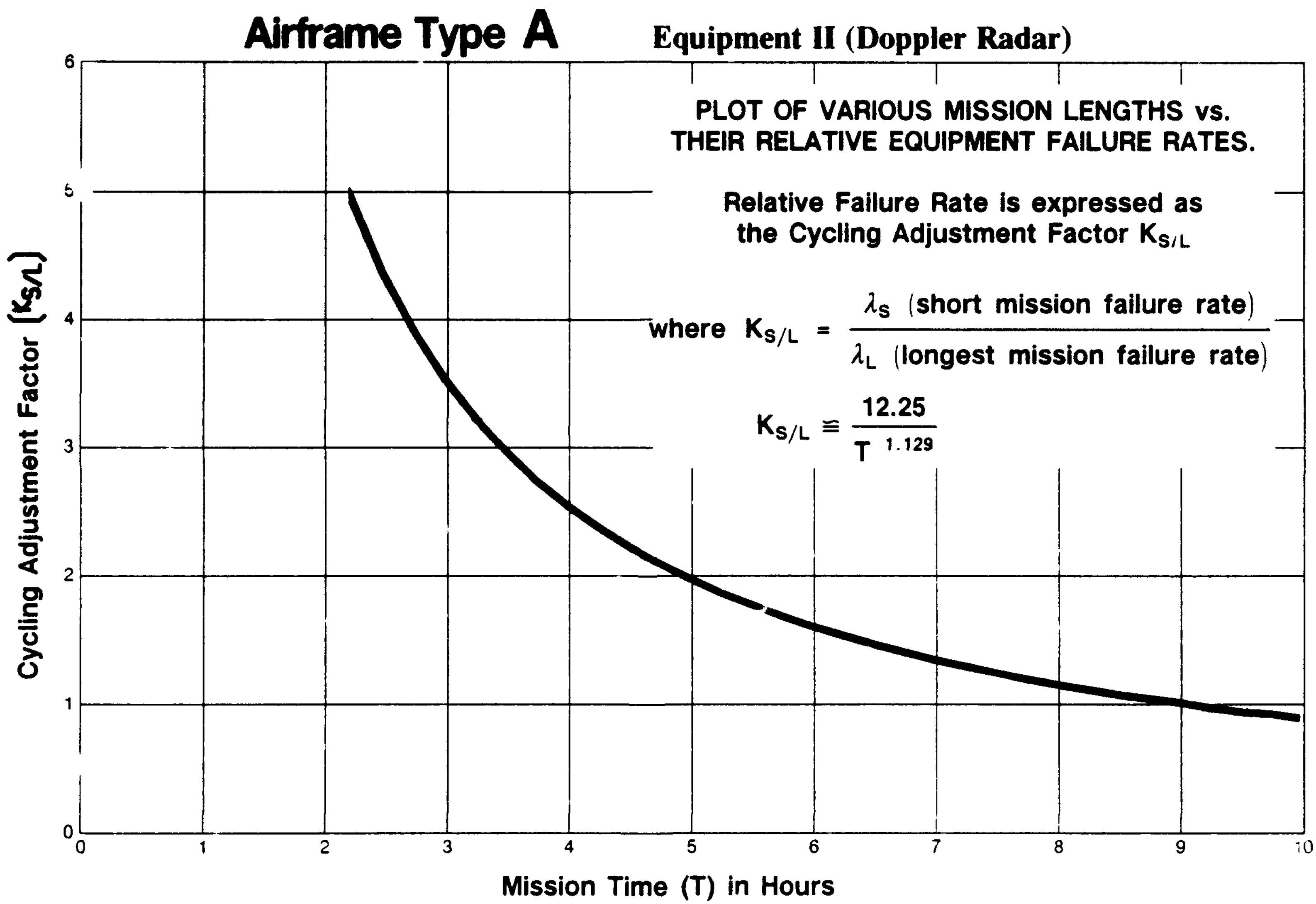

Airframe Type A
Equipment II (Doppler Radar)
PLOT OF VARIOUS MISSION LENGTHS vs.
THEIR RELATIVE EQUIPMENT FAILURE RATES.
Relative Failure Rate is expressed as
the Cycling Adjustment Factor $K_{S/L}$
where $K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$
$K_{S/L} \cong \frac{12.25}{T^{1.129}}$
Cycling Adjustment Factor $(K_{S/L})$
Mission Time (T) in Hours
0
1
2
3
4
5
6
7
8
9
10

Figure 2

Airframe Type A

Table 3. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment III (Flight Director System)

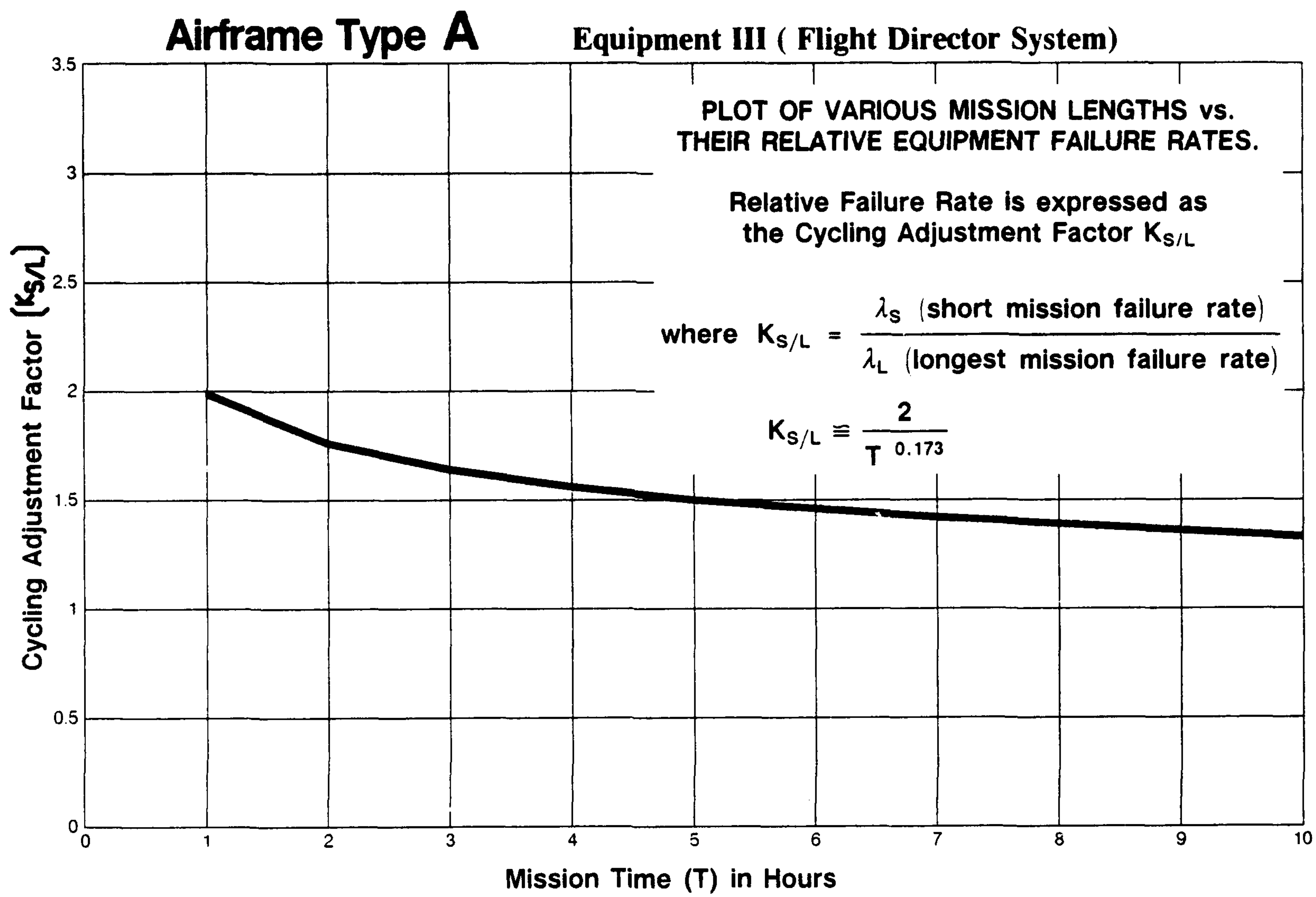
Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A-1	2.20	946	2,082	31	1.08
A-2	3.16	29,652	93,575	956	1.68
A-3	3.94	43,507	172,319	2,644	2.38
A-4	4.49	754	3,376	40	1.98
A-5	5.03	632	3,180	48	2.37
A-6	5.46	4,382	23,942	315	1.58
A-7	7.65	315	2,406	27	1.78
A-8	8.21	1,548	12,705	144	1.01
A-9	9.97	1,301	12,967	178	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$


Airframe Type A
Equipment III (Flight Director System)
PLOT OF VARIOUS MISSION LENGTHS vs. THEIR RELATIVE EQUIPMENT FAILURE RATES.
Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$
where $K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$
$K_{S/L} \cong \frac{2}{T^{0.173}}$
Cycling Adjustment Factor ($K_{S/L}$)
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
9
10
Mission Time (T) in Hours
Figure 3

Airframe Type A

Table 4. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment IV (Autopilot)

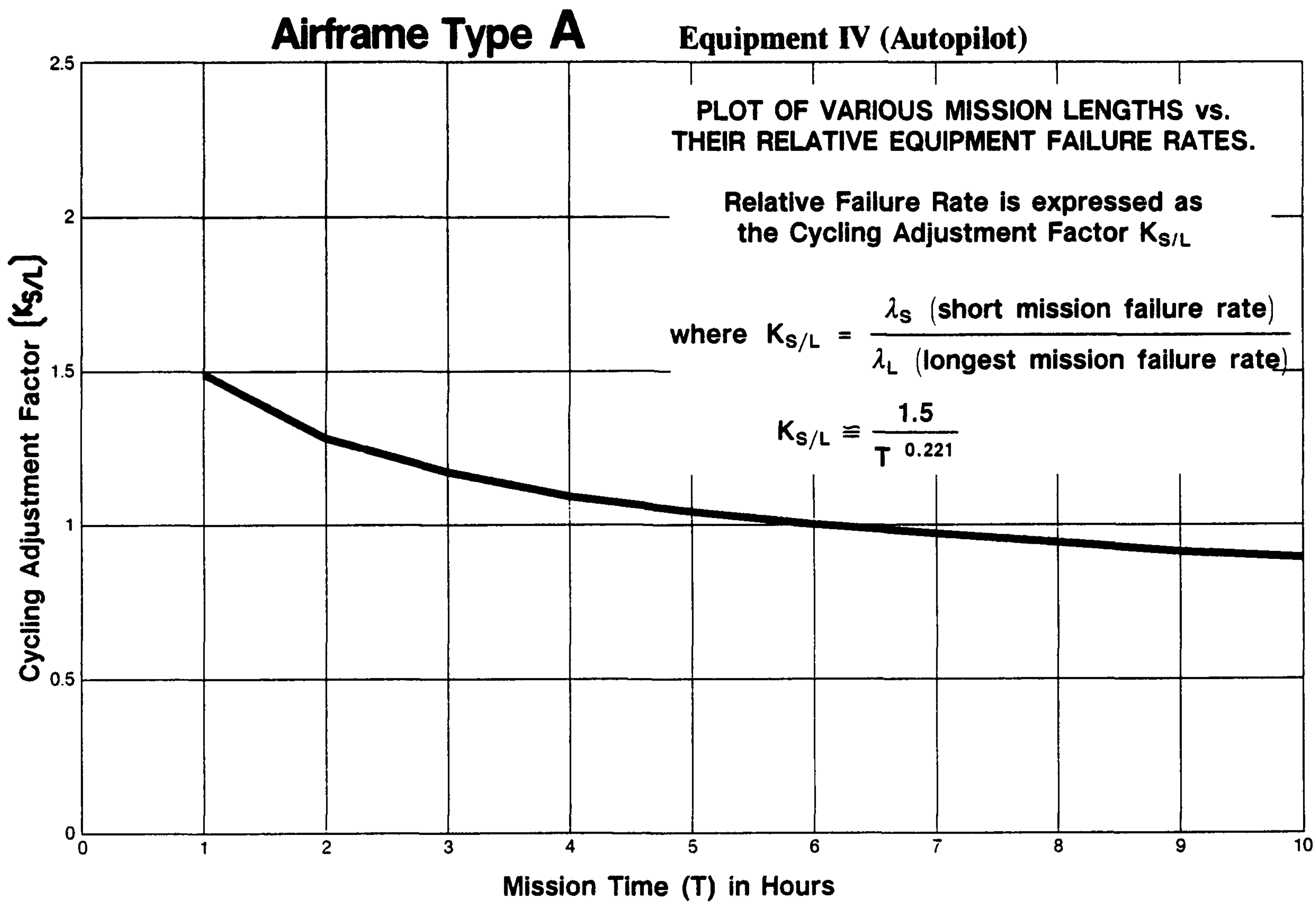
Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A-2	3.16	30,196	95,293	504	1.04
A-3	3.97	50,802	201,600	1,499	1.46
A-4	4.49	754	3,376	19	1.12
A-5	5.03	632	3,180	17	1.08
A-6	5.46	4,382	23,942	246	0.81
A-7	7.65	315	2,406	15	1.18
A-8	8.21	1,548	12,705	133	0.75
A-9	9.97	1,301	12,967	186	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$



Airframe Type A
Equipment IV (Autopilot)
PLOT OF VARIOUS MISSION LENGTHS vs. THEIR RELATIVE EQUIPMENT FAILURE RATES.
Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$
where $K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$
$K_{S/L} \cong \frac{1.5}{T^{0.221}}$
Cycling Adjustment Factor ($K_{S/L}$)
0
0.5
1
1.5
2
2.5
0
1
2
3
4
5
6
7
8
9
10
Mission Time (T) in Hours

Figure 4

Airframe Type A

Table 5. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment V (Tacan)

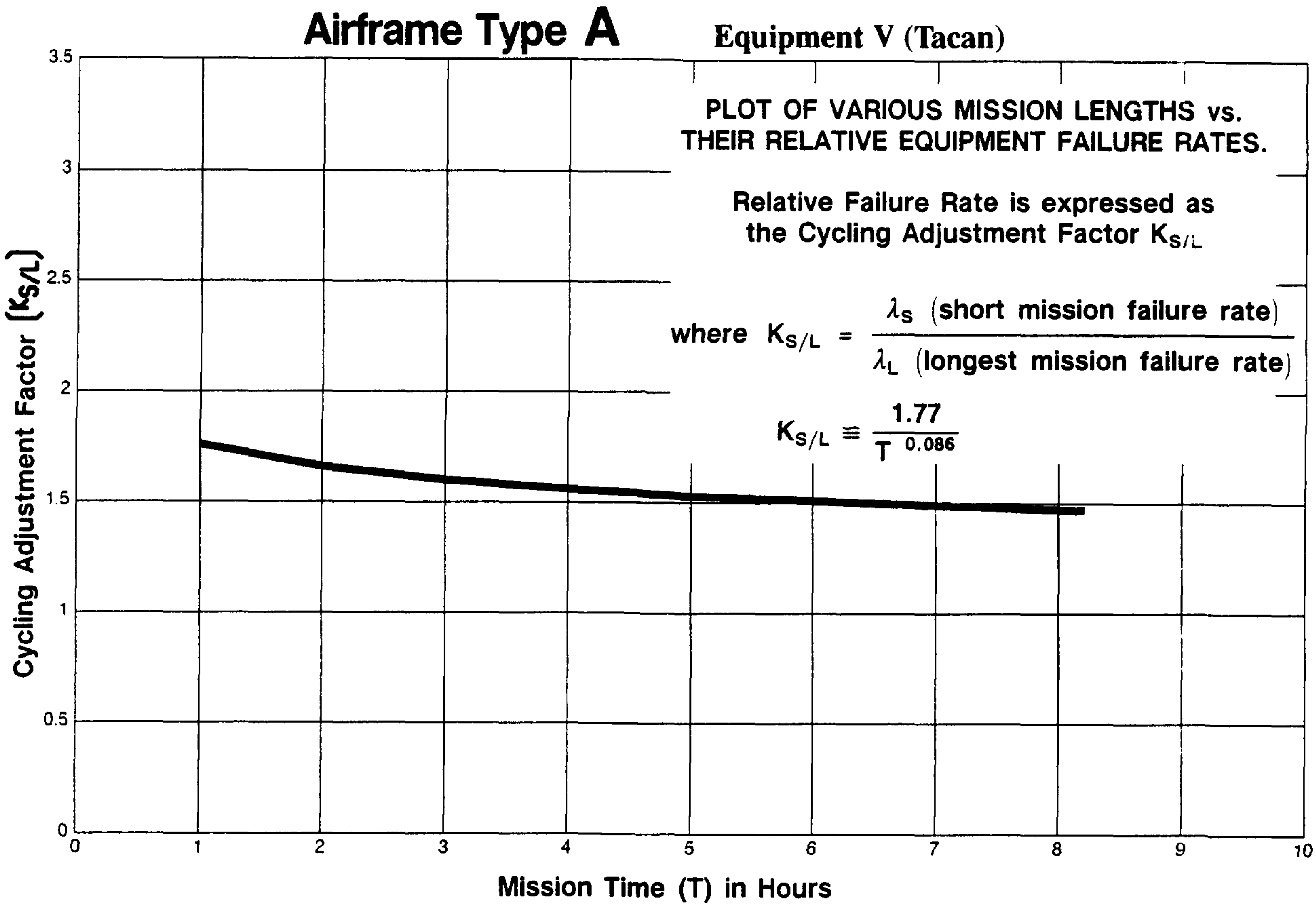
Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A–1	2.20	946	2,082	7	2.51
A–2	3.16	29,652	93,575	93	0.77
A–3	3.94	43,507	172,319	504	2.16
A–4	4.49	754	3,376	5	1.21
A–5	5.03	632	3,180	6	1.33
A–6	5.46	3,663	20,008	46	2.02
A–7	7.65	315	2,406	8	2.51
A–8	8.21	1,548	12,705	17	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$



Airframe Type A
Equipment V (Tacan)
PLOT OF VARIOUS MISSION LENGTHS vs. THEIR RELATIVE EQUIPMENT FAILURE RATES.
Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$
where $K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$
$K_{S/L} \cong \frac{1.77}{T^{0.086}}$
Cycling Adjustment Factor $(K_{S/L})$
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
Mission Time (T) in Hours

Figure 5

Airframe Type A

Table 6. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment VI (Compass System)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
A-1	2.20	946	2,082	6	1.29
A-2	3.16	29,652	93,575	269	1.36
A-3	3.94	43,507	172,319	790	2.18
A-4	4.49	754	3,376	12	1.86
A-5	5.03	632	3,180	9	1.26
A-6	5.46	3,663	20,008	66	1.51
A-7	7.65	315	2,406	21	3.66
A-8	8.21	1,548	12,705	58	2.04
A-9	9.97	1,301	12,967	29	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type A   Equipment VI (Compass System)

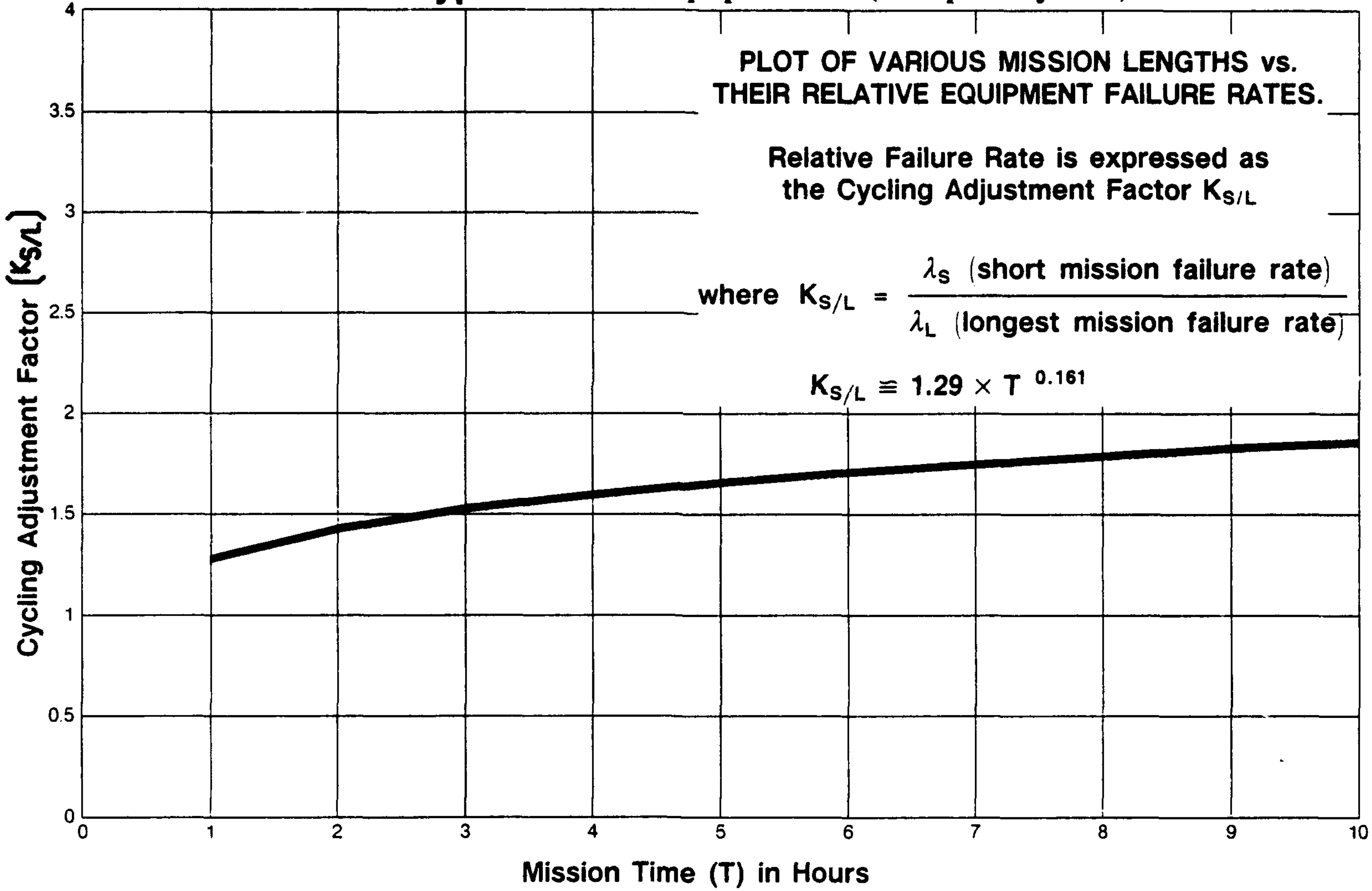


Figure 6

Airframe Type A

Table 7. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

For Airframe Type A Composite

Mission Time (Hours)	$K_{S/L}$	Mission Time (Hours)	$K_{S/L}$
2.20	5.69	5.03	1.26
2.20	2.51	5.03	1.08
2.20	1.29	5.06	2.91
2.20	1.08	5.46	2.02
3.16	5.35	5.46	1.85
3.16	1.88	5.46	1.58
3.16	1.68	5.46	1.51
3.16	1.36	5.46	0.81
3.16	1.04	7.65	3.66
3.16	0.77	7.65	2.51
3.94	3.50	7.65	1.78
3.94	2.38	7.65	0.91
3.94	2.18	7.65	0.83
3.94	2.16	7.65	1.18
3.95	5.50	8.21	2.04
3.97	1.46	8.21	1.01
4.49	6.67	8.21	1.00
4.49	2.09	8.21	0.75
4.49	1.98	9.97	1.00
4.49	1.86	9.97	1.00
4.49	1.21	9.97	1.00
4.49	1.12	9.97	1.00
5.03	3.24	9.97	1.00
5.03	2.37		
5.03	1.33		

A COMPOSITE OF AVIONIC EQUIPMENT TYPES ON A SINGLE AIRFRAME

Airframe Type A Composite

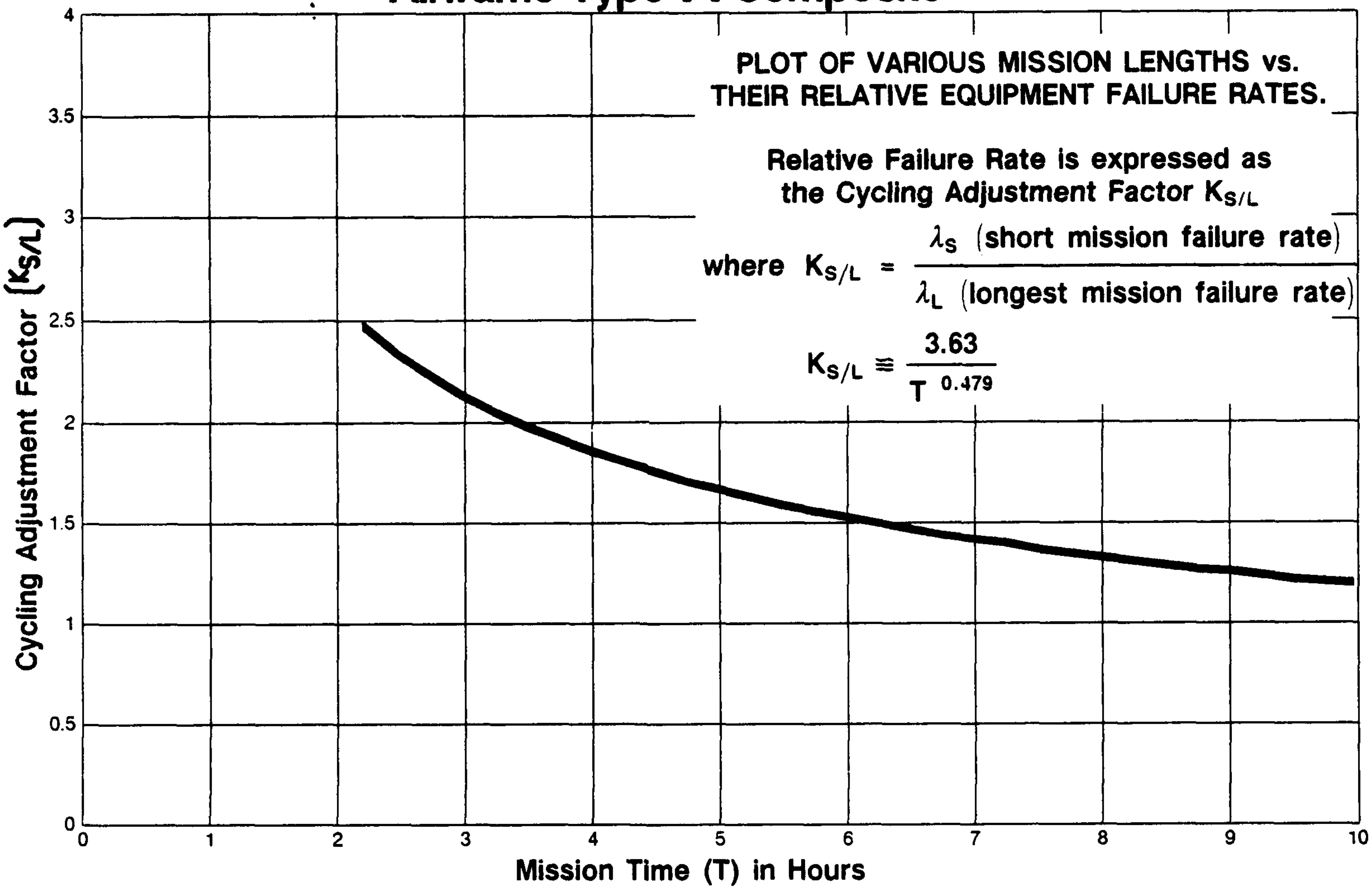


Figure 7

Airframe Type B

Airframe Type B

Table 8. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment VII (Tacan)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B-2	2.03	66,531	134,963	383	1.88
B-3	2.04	31,001	63,294	137	1.43
B-12	3.71	4,049	14,991	32	1.36
B-15	4.83	1,235	5,968	9	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type B

Table 9. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment VIII (UHF Radio)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B-4	2.25	81,539	193,780	241	1.69
B-9	2.79	4,205	11,739	18	2.00
B-13	3.50	4,537	15,643	12	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type B

Table 10. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment IX (IFF Transponder)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B-3	2.04	42,844	87,183	116	2.34
B-6	2.59	47,602	117,346	218	1.41
B-12	3.71	4,049	14,991	9	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type B

Table11. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment X (Flight Director Computer)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B–5	2.45	132,531	324,970	2,964	1.43
B–8	2.76	5,115	14,022	130	1.45
B–11	3.29	4,595	15,012	140	1.43
B–14	3.91	3,991	15,621	103	1.04
B–15	4.83	1,235	5,968	38	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type B

Table 12. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XI (VHF – AM / FM Radio)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B–7	2.66	5,137	13,534	78	4.37
B–10	3.02	5,077	15,331	78	3.82
B–14	3.91	3,991	15,621	56	2.68
B–15	4.83	1,235	5,968	8	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type B

Table 13. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XII (Altitude Encoder)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
B-1	1.95	33,407	67,654	38	2.13
B-4	2.25	81,539	193,780	105	1.89
B-9	2.79	4,205	11,739	4	1.33
B-11	3.29	4,595	15,012	6	1.45
B-14	3.91	3,991	15,621	4	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

A COMPOSITE OF AVIONIC EQUIPMENT TYPES ON A SINGLE AIRFRAME

Airframe Type B

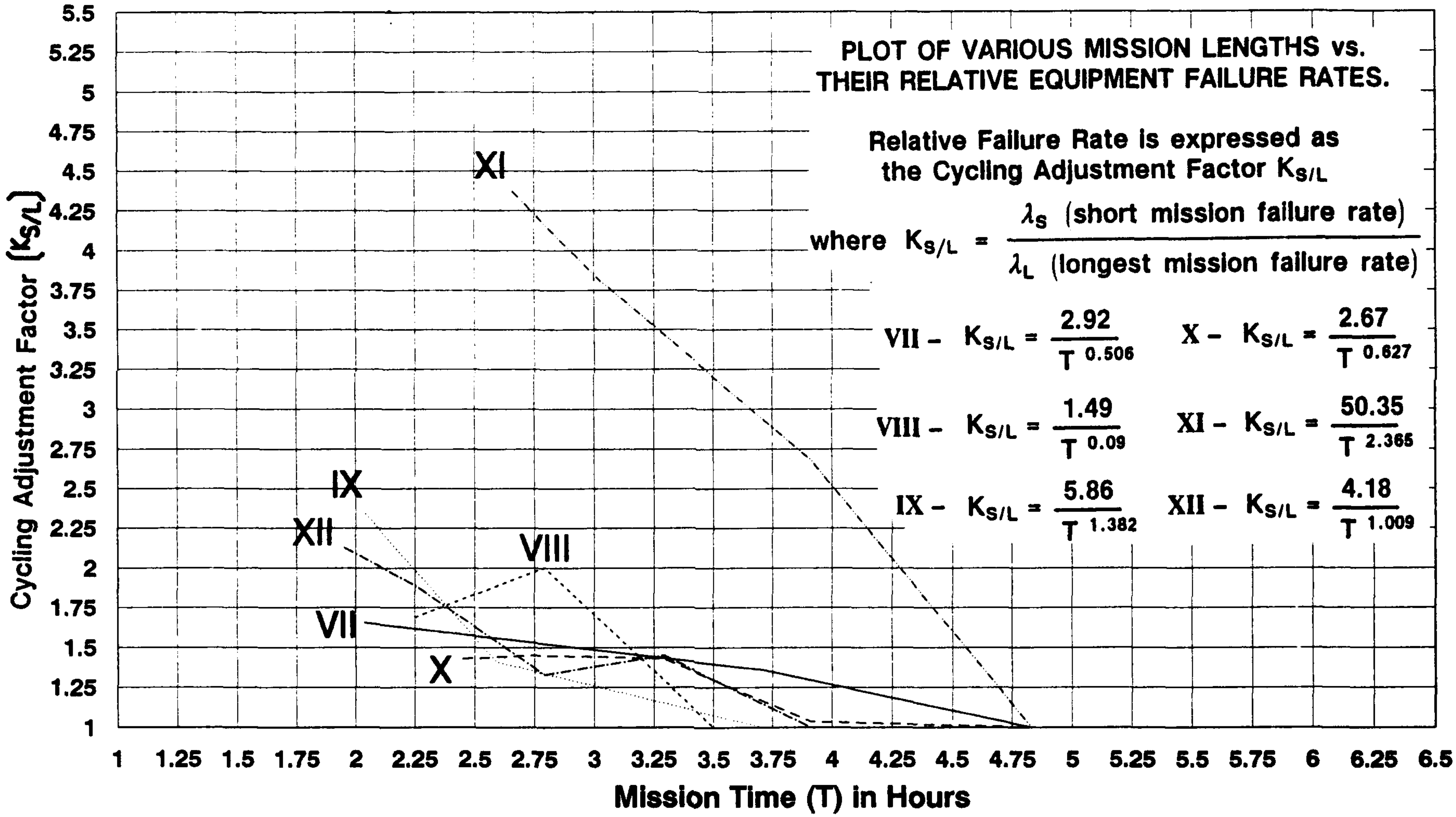


Figure 8

Airframe Type B

Table 14. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

For Airframe Type B Composite

Mission Time (Hours)	$K_{S/L}$
1.95	2.13
2.03	1.88
2.04	2.34
2.04	1.43
2.25	1.89
2.25	1.69
2.45	1.43
2.59	1.41
2.66	4.37
2.76	1.45
2.79	2.00
2.79	1.33
3.02	3.82
3.29	1.45
3.29	1.43
3.50	1.00
3.71	1.36
3.71	1.00
3.91	2.68
3.91	1.04
3.91	1.00
4.83	1.00
4.83	1.00
4.83	1.00

A COMPOSITE OF AVIONIC EQUIPMENT TYPES ON A SINGLE AIRFRAME

Airframe Type B Composite

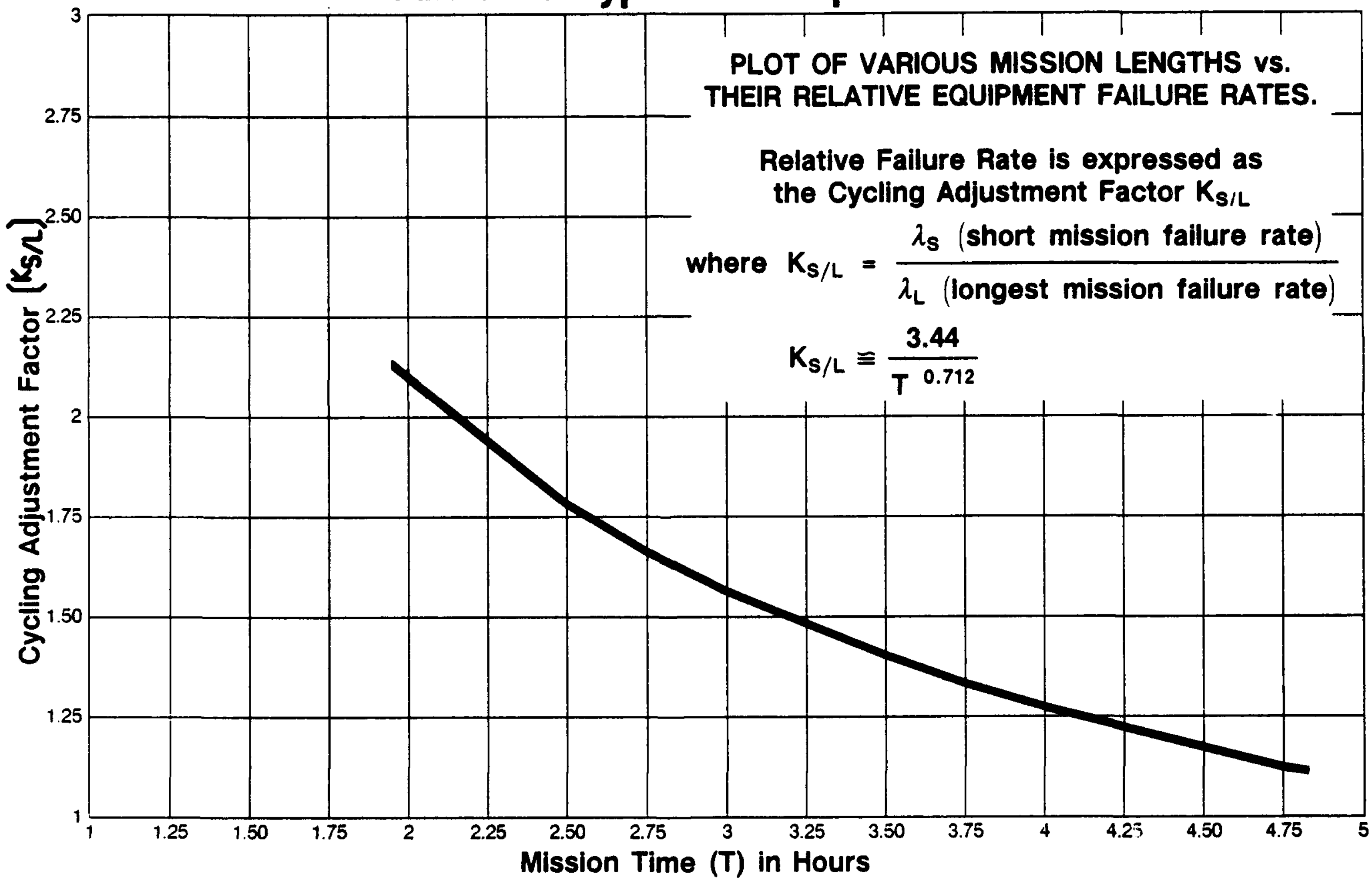


Figure 9

Airframe Type C

Airframe Type C

Table 15. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XIII (Flight Control System)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	13,260	29,534	645	1.76
C-6	3.12	11,866	37,031	431	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \ (\text{Failure Rate}) = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \ (\text{short mission failure rate})}{\lambda_L \ (\text{longest mission failure rate})}$$

Airframe Type C

Table 16. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XIV (UHF Radio)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	13,260	29,534	250	2.81
C-3	2.42	12,464	32,386	116	1.33
C-5	2.82	13,499	37,492	103	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type C

Table 17. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XV (IFF Transponder)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	13,260	29,534	913	2.04
C-3	2.42	13,464	32,386	557	1.34
C-6	3.12	11,866	37,031	534	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type C

Table 18. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XVI (Stall Inhibitor System)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	13,260	29,534	66	1.52
C-3	2.42	13,464	32,386	53	1.16
C-4	2.51	11,866	37,031	56	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type C

Table 19. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XVII (Flight Data Recorder)

Aircraft Configu-ration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	.13,260	29,534	48	1.41
C-2	2.39	17,969	42,929	80	1.39
C-5	2.82	13.499	37.492	51	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

Airframe Type C

Table 20. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

Equipment XVIII (Radar Altimeter)

Aircraft Configuration	Average Mission Time (Hours)	Sorties	Flying Hours	Number of Type 1 Failures	$K_{S/L}$
C-1	2.22	13,260	29,534	667	1.32
C-5	2.82	13,499	37,492	434	1.00

$$\text{Mission Time} = \frac{\text{Flying Hours}}{\text{Sorties}}$$

$$\lambda_S \text{ (Failure Rate)} = \frac{\text{Flying Hours}}{\text{Failures}}$$

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

A COMPOSITE OF AVIONIC EQUIPMENT TYPES ON A SINGLE AIRFRAME

Airframe Type C

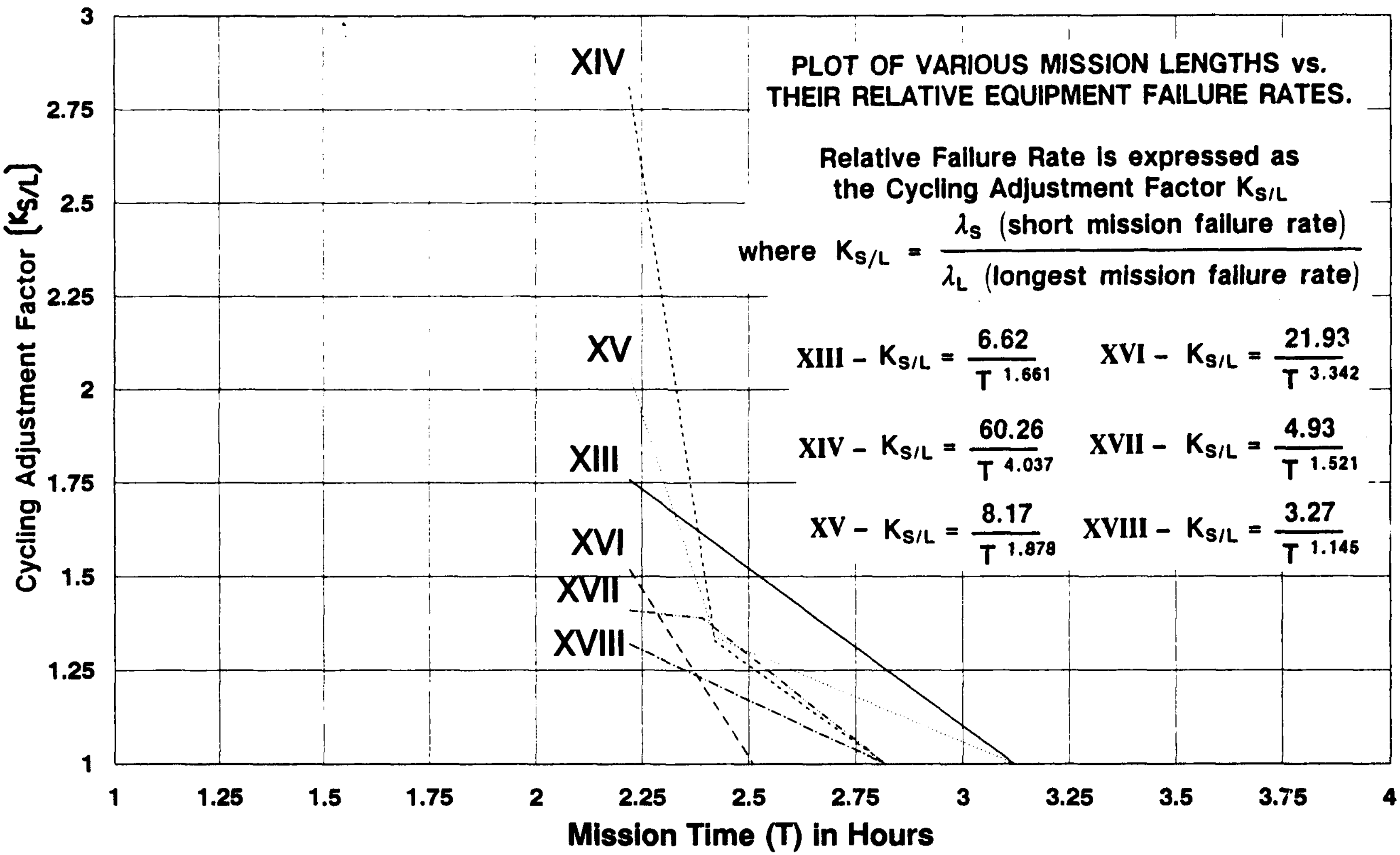


Figure 10

Airframe Type C

Table 21. Tabulation of Various Mission Lengths and Relative Failure Rates Expressed as Cycling Adjustment Factor $K_{S/L}$

For Airframe Type C Composite

Mission Time (Hours)	$K_{S/L}$
2.22	2.81
2.22	2.04
2.22	1.76
2.22	1.52
2.22	1.41
2.22	1.32
2.39	1.39
2.42	1.34
2.42	1.33
2.42	1.16
2.51	1.00
2.82	1.00
2.82	1.00
2.82	1.00
3.12	1.00
3.12	1.00

Relative Failure Rate is expressed as the Cycling Adjustment Factor $K_{S/L}$

$$\text{where } K_{S/L} = \frac{\lambda_S \text{ (short mission failure rate)}}{\lambda_L \text{ (longest mission failure rate)}}$$

A COMPOSITE OF AVIONIC EQUIPMENT TYPES ON A SINGLE AIRFRAME

Airframe Type C Composite

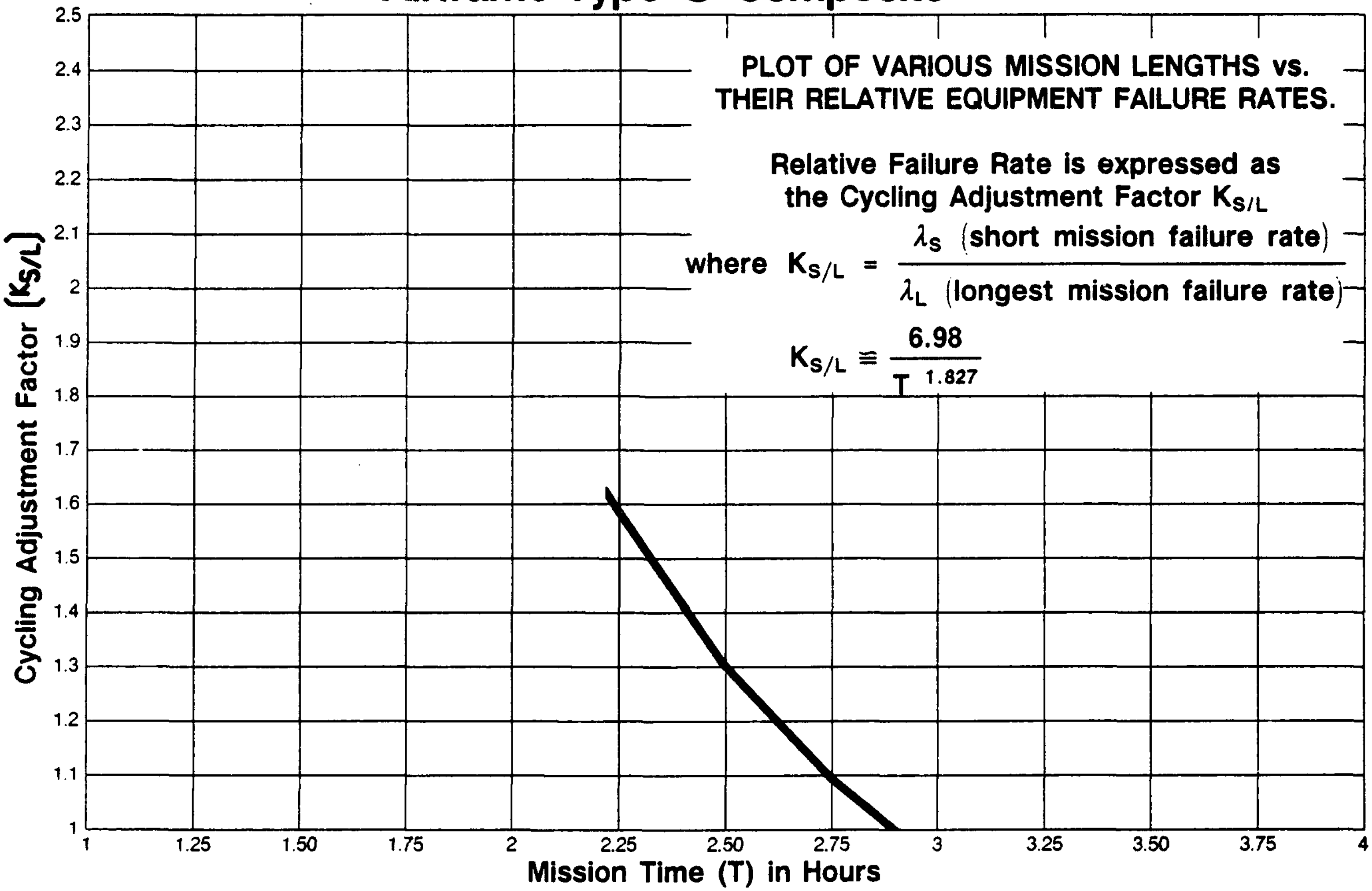


Figure 11

4.3 Equipment React Differently to Cyclic Operation

The six pieces of equipment which were examined on aircraft type A represent a range of avionic equipment. They included different equipment functions and different periods of equipment design. It should be recognized that this variety of equipment will have different vulnerability to on-off cycling even under similar conditions of environment (similar conditions which were attempted to maintain in the database by using a single type airframe for comparative data).

The plots of $K_{S/L}$ for the six pieces of equipment on airframe "A" indicate this difference in the effect of cycling on different equipment. These effects have been to the greatest extent possible, isolated from the additional effect of environment such that it is practical to obtain desired data of the operational environment.

Qualitative data from discussions at air bases indicates that susceptibility to cyclic failure (and failures in general) seem to be made worse by elevated ramp temperatures and the presence of highly humid conditions.

Conversations with designers in industry and maintenance personnel in the Air Force indicate a belief that increases in failure rate due to cycling are for the most part related to increases and decreases of temperature in the cycling process. This produces successive mechanical stress at vital connection points. This progressive stress application is particularly damaging in points of stress concentration or in areas where chemical activity has created an irregular condition.

Use of this data for prediction of operational performance of equipment under conditions of cyclic operation should recognize the differences in the way different equipment reacts to the effects of cycling service. Where possible, the $K_{S/L}$ factor for equipment similar to that being considered should be used.

4.4 Summation of Findings Relative to the Study Hypothesis

On all three airframe types that were studied, there appears to be a relationship that suggests that "on/off" cycling has a negative impact on failure rate. It is obvious from the various plots that some systems appear to be more sensitive to cycling than others. Further, the combining of the data from two or more airframe types on the same plot is not done here because of the probability of variation in environmental conditions. When comparing the same systems/equipment mounted on different airframes, the $K_{S/L}$ for approximately the same T (mission time) are different; partially attributable to environmental differences, and partially due to the different baseline (longest mission time).

4.5 Generalized Cycling Algorithm

The analysis of cycling presented in this study and its effects on reliability do show a trend giving a direct relationship between mission time and failure rate. A variety of mathematical methods were considered to express this relationship. A multi-term series expression was considered. Finally, a simple single term equation was found to provide a suitable fit for the data in the general form:

$$K_{S/L} = \frac{C}{T^{a}}$$

This was evaluated specifically for the A type airframes. Using the combined plot shown in Figure 7, the relationship is defined as

$$K_{S/L} \cong \frac{3.63}{T^{0.479}}$$

The application of this relationship should be of particular interest to the equipment user faced with the decision of selecting the best mode of equipment operation within the constraints of his mission. The relationship should also be useful when predicting reliability in airborne applications where short mission lengths are encountered. Using the plots or the algorithm as a guide, equipment usage policies can be reviewed.

This algorithm could be useful to the equipment designer since it allows the cycling and reliability question to be considered in the design process.

Since the algorithm is derived from a large amount of field data, it must be considered empirical in nature. It represents a reasonable approach to describe the cycling phenomena numerically. This expression may change over time with changes in equipment design practice and should receive periodic review. In the absence of better data, this represents the best estimate to date of the cycling impact on reliability prediction.

4.6 Induced and Cannot Duplicate (CND) Failures

A review of data relating to "Induced" and "Cannot Duplicate" failures was made along with the analysis of the "Inherent" failures. Interviews with maintenance personnel at various Air Force bases revealed that induced failures usually result from a variety of causes that seem to occur randomly. In any case, these are fortuitous happenstances and are not directly related to "on/off" cycling except for the few extra cycles associated with troubleshooting and repair which adds to the total number of cycles experienced by the equipment/systems.

Again, as with "Induced" failures, discussions with Air Force maintenance personnel indicate the "Cannot Duplicate" failures usually occur randomly. There is no physical evidence to support a relationship between "Cannot Duplicate" failures and cycling failures except for the extra cycles imposed by fault analysis and classification. A review of data for both "Induced" and "Cannot Duplicate" failures was made. The data appeared to be so random that no correlation with cycling could be found.

4.7 Application and Testing of the Cycling Algorithm

It is necessary to test the predictive accuracy of these results in systems that were not used in the formulation of the algorithm. Table 22, titled "Test Systems For Inherent Failures (Systems Not Used in the Formulation of the Predictive Algorithm)", shows the MIL-HDBK-217 prediction ($MTBF_{217}$), the cycle modified MIL-HDBK-217 prediction ($MTBF_p$), and the observed $MTBF_o$ for four equipment/systems and platform combinations. It is clear that the $MTBF_p$ is a more accurate prediction than the basic MIL-HDBK-217 prediction in these four situations.

Table 22. Test Systems for Inherent Failures
(Systems Not Used in the Formulation of the Predictive Algorithm)

Aircraft Platform	Mission Time T (Hours)	Observed $MTBF_o$	Predicted $MTBF_{217}$	Adjustment Factor $K_{S/L}$	Modified $MTBF_p$
1	1.31	53	540	3.19	169.28
2	6.59	522	1878	1.47	1277.55
3	4.40	383	1878	1.79	1049.16
4	4.40	33	55	1.79	30.73

5.0 QUALITATIVE FINDINGS AND FIELD EXPERIENCE WITH CYCLIC FAILURE IN AIRBORNE ELECTRONIC EQUIPMENT

It is generally accepted that the mechanisms which produce the additional failures from the cyclic operation of electronic equipment are not fully understood. However, many elements of the process seem to be well supported by Air Force data and the experience of those who are closely related to the equipment operations.

It is generally accepted that cycling increases the failure rate of electronic equipment beyond that of the steady state performance. The source of this cyclic degeneration has been normally presumed to be the electrical stress and the reheating cycle which attends the start of the equipment.

A series of initial conferences with persons close to the operation of many kinds of airborne electronics (designers, operators, and maintenance personnel) have indicated that there are many special field conditions which, in addition to cycling, affect equipment reliability.

In pursuit of qualitative data, we have conducted interviews on this subject with factory test personnel, repair depot technicians, Westinghouse field service personnel, and a variety of senior electronic designers. We have researched the literature on this subject. We have also held conferences with groups of Air Force technicians and maintenance officers. In addition, we have questioned material and electronic experts at our Research and Development Laboratories at Pittsburgh.

The summation of all of this searching has revealed the generally accepted belief that the damaging effects of cycling are very real, and that they are most related to temperature changes.

Electrical and thermal stress are no doubt basic to the increases in failure rate from cycling, but there are a variety of additional elements which condition the severity of these occurrences.

Moisture may be one of the most significant of these. The gathering of moisture on components during off periods was mentioned by almost every maintenance group.

When the moisture dried faults most often disappeared but they reported that retained moisture had caused many false removals.

Transient power surges were sited as a significant element in equipment failure. Changes in voltage level would then add to the cyclic stress of the start-up condition.

Normal landing shock is known to produce mechanical stresses and distortions which would tend to extend tiny cracks or change contact coupling in ways which expand the cyclic stress effect and extend the vulnerability of the system to cyclic stress effect.

The combination of moisture, heat, and airborne corrosive agents combine to make contact corrosion an element noted by almost all of the experienced experts we interviewed. The resulting increases in resistance seem to combine with the effects of cyclic stress to produce a progressively degenerative system.

Excessive equipment heating, which results from high ambient temperature or operation on ramps with limited cooling capacity, has been specified as causing physical deterioration in contact area and deterioration of dielectric materials. These effects increase sensitivity to the cyclic stress condition.

The combination of these and other mechanisms combine, in some complex fashion, to produce degenerative incipient failure mechanisms. The operation of these mechanisms continue to diminish the ability of a system to withstand the stress of cyclic operation.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions reached from this study are:

1. The higher the "on-off" cycling rate, the higher the failure rates will be experienced.

2. The algorithms developed by this study can be used in conjunction with MIL-HDBK-217 for reliability predictions if the user is conscious of the limitation of data and the lack of environmental information in the operations.

The results of this study suggest that the algorithm that was developed here be used for reliability predictions for systems where there is no field data available. This would be especially true for new equipment designs. It must be understood that this adjustment to the MIL-HDBK-217 reliability prediction will not produce an exact result, but it provides a macro adjustment. It is expected that the use of this algorithm will improve the accuracy of reliability predictions.

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APPENDIX

Definitions and Terms

Specific definition of terms used in this report in a specialized sense are given below:

A. Component. An item that is not operationally useful by itself and not subject to disassembly for repair.[1]

B. Cycle. One cycle in time sequence, consists of (1) the application of power, (2) the operation of the equipment, and (3) the removal of power.

C. Cycle Time. Aircraft flight hours divided by the number of on/off cycles.

D. Cycling. The application of power to an equipment and the subsequent removal of power from the equipment.[1]

E. Equipment. A functional assembly of components that, when energized, is operationally useful either by itself or in association with other equipment.[1]

F. Failure. The malfunction of an equipment or system that results in unsatisfactory performance.[1]

G. Mission Time. Aircraft flight hours divided by the number of sorties.

H. Reliability. The probability that avionic equipment/system will perform properly for a given mission when used for its intended purpose.[1]

I. Sorties. A mission involving the take off and landing of an aircraft.

J. System. A functional assembly of components and/or equipment that, when energized, is operationally useful either by itself or in association with other systems.[1]

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