DATA-INFORMED ENVIRONMENTAL CONVERSION

UPDATING MIL-HDBK-217 AND -338 WITH 50+ YEARS OF FIELD DATA

PREPARED FOR RAMS TRAINING SUMMIT XIV

NOVEMBER 1-2, 2022

HUNTSVILLE, AL, US

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WHAT IS AN ENVIRONMENT?

- Describes a set of conditions in which a component operates
- While every operating condition is unique, most are ‘close enough’ to a few common definitions
- Includes temperature, humidity, radiation, field effects, shock, vibration, etc.

EARTHBOUND ENVIRONMENT DEFINITIONS (MIL-HDBK-338B)

Environment	Symbol	Conditions
Ground, Benign	GB	Static, temperature and humidity controlled. No shock or vibration.
Ground, Fixed	GF	Static, not temperature or humidity controlled. No shock or vibration.
Ground, Mobile	GM	Vibration and shock present. Often installed in a wheeled or tracked vehicle.
Naval, Sheltered	NS	Above or below-decks on sea vehicles. Sheltered from sea air.
Naval, Unsheltered	NU	Unprotected shipborne equipment, exposed to weather and salt water.

AEROSPACE ENVIRONMENT DEFINITIONS (MIL-HDBK-338B)

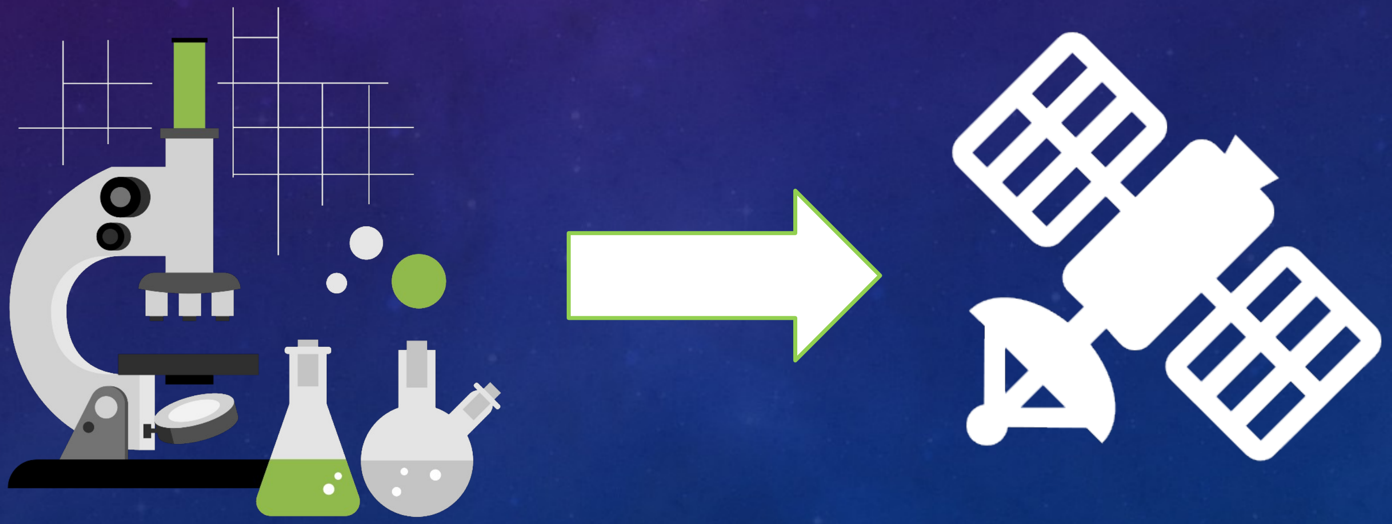
Environment	Sbl.	Conditions
Space, Flight	SF	Earth Orbiting, not powered flight or reentry. Vibe/Shock/Temp similar to GB, but increased radiation.
Airborne, Inhabited, Cargo	AIC	Typical conditions of crewed cargo compartments, without environmental pressure, temp, shock or vibe extremes.
Airborne, Inhabited, Fighter	AIF	As AIC, but high Vibration and shock present. Installed on High-Performance fighter / interceptor aircraft.
Airborne, Uninhabited, Cargo	AUC	Uncontrolled airborne areas with environmental extremes of pressure, temperature, vibe and shock.
Airborne, Uninhabited, Fighter	AUF	As AUC, but installed on High Performance aircraft and subjected to more extreme extremes.
Airborne, Rotary Winged	ARW	Equipment installed internally and externally on helicopters.

MISSILE ENVIRONMENT DEFINITIONS (MIL-HDBK-338B)

Environment	Sbl.	Conditions
Missile, Launch	ML	Severe noise, vibe, and environmental extremes. Missile launches, space vehicle launch, reentry.
Missile, Flight	MF	Atmospheric flight to target

UNDERSTAND ENVIRONMENTAL CONVERSION

Gadget A *has been tested in your lab, a Ground Benign (GB) environment, and its reliability in this context is well understood. Your customer wants to integrate it into a satellite, which will operate in the Space Flight (SF) environment. Without access to reliability figures of merit for SF, how can you perform Reliability Analysis for your customer's projected use of* Gadget A?



UNDERSTAND ENVIRONMENTAL CONVERSION

The lead engineer for a Big Cargo Ship *is considering removing the deck from above the generator room, as a cost-saving measure. As the RE for a generator that will be stored in that room, you need to quantify the effect this will have on your product's reliability and availability. However, this generator has never been operated in the NU environment.*

UNDERSTAND ENVIRONMENTAL CONVERSION

These situations can be modeled with Systems Reliability Engineering tools. Originally described in MIL-HDBK-217 and superseded by MIL-HDBK-338, techniques exist for converting between a known condition (quality, temperature, or environment) to an undemonstrated condition.

This is made possible by extensive study of the changes arising in well-studied parts when subjected to different conditions.

UNDERSTAND ENVIRONMENTAL CONVERSION

For Example:

The same part & grade, has the following MTBFs by environment:

Environment	FPMH
GF	1
GM	1.5
AUF	5
SF	.75

With environment being the only changed variable, we conclude that the effect on FPMH is due to the environment.

Conversion	Ratio
GF to GM	1.5
GM to GF	.667
GF to AUF	5
AUF to SF	.15

If many different parts all experience similar effects, we can arrive at a general effect of each environment on reliability

HISTORY OF ENVIRONMENTAL CONVERSION

- MIL-HDBK-217, published in 1965
- Superseded
- Last release was MIL-HDBK-338B, 1998

TABLE 10.3-3: ENVIRONMENTAL CONVERSION FACTORS
(MULTIPLY SERIES MTBF BY)

From Environment	To Environment: G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Environmental Factors as Defined in MIL-HDBK-217

UNDERSTAND ENVIRONMENTAL CONVERSION

Gadget A *has been tested in your lab, a Ground Benign (GB) environment, and its reliability in this context is well understood. Your customer wants to integrate it into a satellite, which will operate in the Space Flight (SF) environment. Without access to reliability figures of merit for SF, how can you perform Reliability Analysis for your customer's projected use of* Gadget A?

				To Environment							
G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Gadget A MTBF in GB = 100,000 hours

GB to SF conversion factor = 1.2

Gadget A expected MTBF in SF = 120,000 hours

UNDERSTAND ENVIRONMENTAL CONVERSION

The lead engineer for a Big Cargo Ship *is considering removing the deck from above the generator room, as a cost-saving measure. As the RE for a generator that will be stored in that room, you need to quantify the effect this will have on your product's reliability and availability. However, this generator has never been operated in the NU environment.*

	To Environment										
	G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Generator MTBF in NS = 50,000 hours

NS to NU conversion factor = .5

Generator expected MTBF in NU = 25,000 hours

LIMITATIONS TO THE MIL-HDBK APPROACH

- Table is not commutative (upper and lower sides are not reciprocals)
- Reciprocal allow converting between environments without noise or bias
- Lack of precision in conversion factors limits MTBF estimates

TABLE 10.3-3: ENVIRONMENTAL CONVERSION FACTORS
(MULTIPLY SERIES MTBF BY)

From Environment	To Environment										
	G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Environmental Factors as Defined in MIL-HDBK-217

LIMITATIONS TO THE MIL-HDBK APPROACH

To Environment

	G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Generator MTBF in NS = 50,000 hours

NS to NU conversion factor = .5

Generator expected MTBF in NU = 25,000 hours

To Environment

	G_B	G_F	G_M	N_S	N_U	A_{IC}	A_{IF}	A_{UC}	A_{UF}	A_{RW}	S_F
G_B	X	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
G_F	1.9	X	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
G_M	4.6	2.5	X	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
N_S	3.3	1.8	0.7	X	0.5	1.0	0.7	0.4	0.2	0.3	3.8
N_U	7.2	3.9	1.6	2.2	X	2.2	1.4	0.9	0.5	0.7	8.3
A_{IC}	3.3	1.8	0.7	1.0	0.5	X	0.7	0.4	0.2	0.3	3.9
A_{IF}	5.0	2.7	1.1	1.5	0.7	1.5	X	0.6	0.4	0.5	5.8
A_{UC}	8.2	4.4	1.8	2.5	1.2	2.5	1.6	X	0.6	0.8	9.5
A_{UF}	14.1	7.6	3.1	4.4	2.0	4.2	2.8	1.7	X	1.4	16.4
A_{RW}	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	X	11.9
S_F	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	X

Generator MTBF in NU = 25,000 hours

NU to NS conversion factor = 2.2

Generator expected MTBF in NS = 55,000 hours

55,000 != 50,000

LIMITATIONS TO THE MIL-HDBK APPROACH

TABLE 10.3-3 Environmental Conversion Factors from MIL-HDBK-338B

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
GF	1.9	1	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
GM	4.6	2.5	1	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
NS	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.8
NU	7.2	3.9	1.6	2.2	1	2.2	1.4	0.9	0.5	0.7	8.3
AIC	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.9
AIF	5	2.7	1.1	1.5	0.7	1.5	1	0.6	0.4	0.5	5.8
AUC	8.2	4.4	1.8	2.5	1.2	2.5	1.6	1	0.6	0.8	9.5
AUF	14.1	7.6	3.1	4.4	2	4.2	2.8	1.7	1	1.4	16.4
ARW	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	1	11.9
SF	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1

TABLE 10.3-3 with reciprocal right-hand side

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1	0.53	0.22	0.3	0.14	0.3	0.2	0.12	0.07	0.1	1.11
GF	1.9	1	0.4	0.56	0.26	0.56	0.37	0.23	0.13	0.18	2
GM	4.6	2.5	1	1.43	0.63	1.43	0.91	0.56	0.32	0.45	5
NS	3.3	1.8	0.7	1	0.45	1	0.67	0.4	0.23	0.31	3.33
NU	7.2	3.9	1.6	2.2	1	2	1.43	0.83	0.5	0.71	10
AIC	3.3	1.8	0.7	1	0.5	1	0.67	0.4	0.24	0.32	3.33
AIF	5	2.7	1.1	1.5	0.7	1.5	1	0.63	0.36	0.48	5
AUC	8.2	4.4	1.8	2.5	1.2	2.5	1.6	1	0.59	0.77	10
AUF	14.1	7.6	3.1	4.4	2	4.2	2.8	1.7	1	1.43	10
ARW	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	1	10
SF	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1

LIMITATIONS TO THE MIL-HDBK APPROACH

- The percent difference between the published values and the reciprocals is shown to the right
- In some cases the published values are almost 40% off from the desired true reciprocal
- See work of Frank Hark And Steven Novack in 2017 presentation "MIL-HDBK-338 Environmental Conversion Table Correction"

Percent Difference between Published and Reciprocals

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%	5%	9%	1%	39%	1%	0%	22%	-29%	-2%	-7%
GF	0%	0%	0%	-7%	-15%	-7%	-7%	14%	32%	-9%	-9%
GM	0%	0%	0%	2%	-11%	2%	1%	-7%	8%	-9%	-7%
NS	0%	0%	0%	0%	-9%	0%	-5%	0%	14%	4%	-12%
NU	0%	0%	0%	0%	0%	-9%	2%	-7%	0%	2%	20%
AIC	0%	0%	0%	0%	0%	0%	-5%	0%	19%	8%	-15%
AIF	0%	0%	0%	0%	0%	0%	0%	4%	-11%	-5%	-14%
AUC	0%	0%	0%	0%	0%	0%	0%	0%	-2%	-4%	5%
AUF	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	-39%
ARW	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-16%
SF	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

LIMITATIONS TO THE MIL-HDBK APPROACH

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Percent Difference between Published and Reciprocals

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%	5%	9%	1%	39%	1%	0%	22%	-29%	-2%	-7%
GF	0%	0%	0%	-7%	-15%	-7%	-7%	14%	32%	-9%	-9%
GM	0%	0%	0%	2%	-11%	2%	1%	-7%	8%	-9%	-7%
NS	0%	0%	0%	0%	-9%	0%	-5%	0%	14%	4%	-12%
NU	0%	0%	0%	0%	0%	-9%	2%	-7%	0%	2%	20%
AIC	0%	0%	0%	0%	0%	0%	-5%	0%	19%	8%	-15%
AIF	0%	0%	0%	0%	0%	0%	0%	4%	-11%	-5%	-14%
AUC	0%	0%	0%	0%	0%	0%	0%	0%	-2%	-4%	5%
AUF	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	-39%
ARW	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-16%
SF	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

LIMITATIONS TO THE MIL-HDBK APPROACH

- Only meant for electrical components
- Does not account for radiation
- Based largely on only 4 component varieties – limited use beyond these components
- However, still widely used as if it was valid for all parts, electric and non-electric

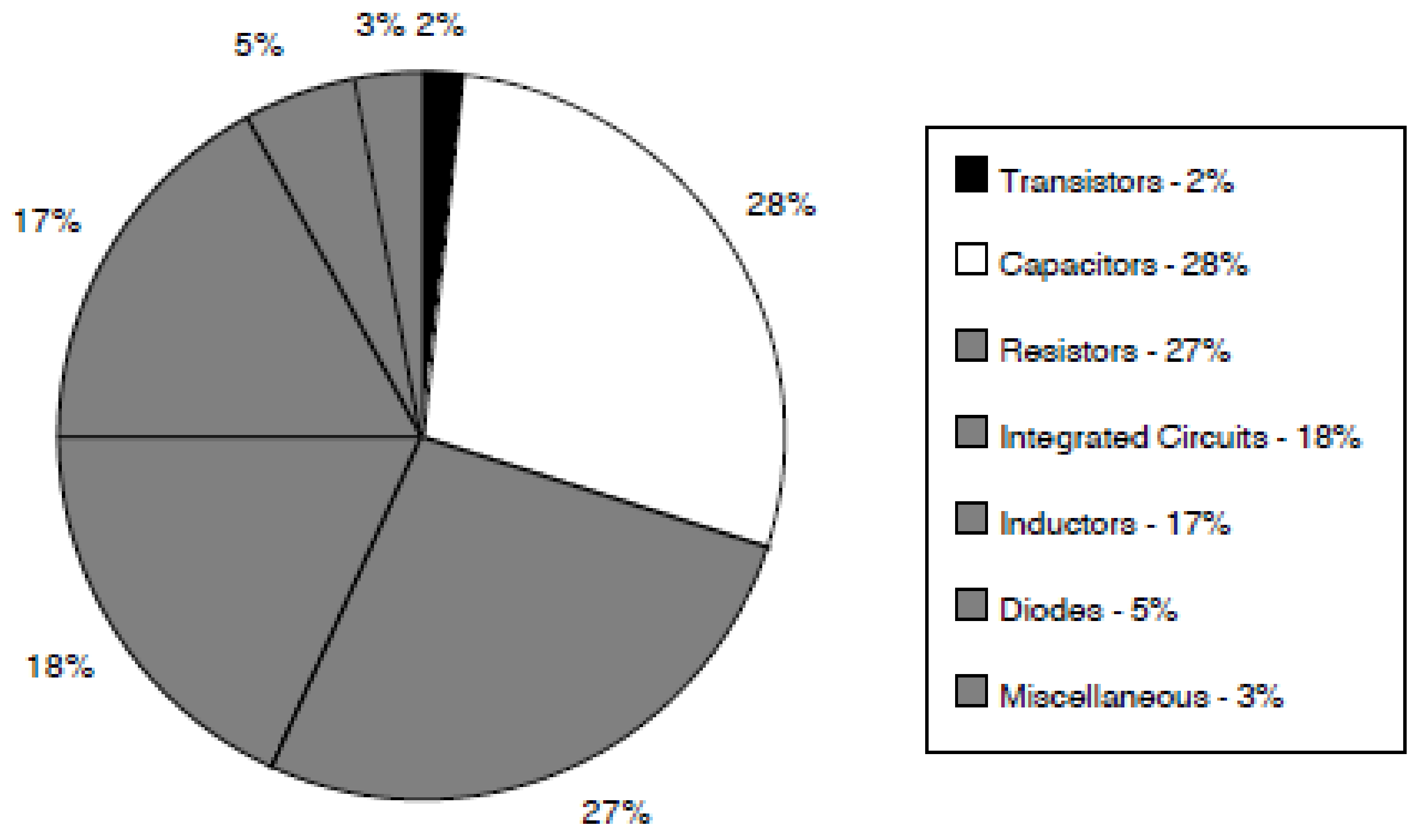

FIGURE 10.3-1: PART DATABASE DISTRIBUTION

SOLUTION – UPDATE THE MIL-HDBK APPROACH

- Now have 50+ years of field data beyond what was available to MIL-HDBK-217 authors in 1965
- Update the Environmental Conversions Table for Electrical-Only components
- Build a new table for *All Parts*, electric and mechanical
- Questions on applications and history of Environmental conversion?

A LOOK AT THE DATA

- What field data is available?
- Why should we trust this data?
- How limited is the available data?

WHAT FIELD DATA IS AVAILABLE?

- Military specs and studies
- Government database
- Industry / Private database

WHY SHOULD WE TRUST THIS DATA?

- Dependent on source
- In general, tests performed over like lots and large sample time
- In this meta-study, data cleaning including removing outliers can control for misreporting

HOW LIMITED IS THE AVAILABLE DATA?

	Constituent Failure Rates										
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
n# rates	35	140	89	75	56	68	75	115	75	17	745

- Limited data in GB and SF environments
- No data in NU, ML, MF environment
- Certain part varieties are not well represented
- Mechanical Data across many environments is not plentiful

A LOOK AT THE METHODOLOGY

- Examine notional data (cannot share proprietary data)
- Criteria for including data in this analysis
- Demonstrate the method to build a new table

NOTIONAL DATA

- Each of these lines is a study of a part series in a certain grade and environment.
- Reports Hours of operation (in million hours) and # failures

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Component cannot be used for this analysis, even though it was used in different environments

The parts are of different grades, which may account for the difference in failure rate

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Fidget is a great source – A fidget of COTS quality was used in three different environments.

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Fidget is a great source – A fidget of COTS quality was used in three different environments.

Fidget's data suggests the following conversion factors:

Component	GF to AUF	GF to SF	AUF to SF
Fidget	1.008	.276	.273

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Even though *Gadget* is heavily studied, it was only used in one environment and cannot be used for this analysis.

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Item has also only been studied in one environment

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Part provides two data points to this analysis:

A military-grade part converting between GM and GF

A commercial-grade part converting between GM and GF

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
Gadget	Military	AUF	2	7.800	3.900
Gadget	Military	AUF	7	24.860	3.551
Gadget	Military	AUF	7	32.200	4.600
Gadget	COTS	AUF	4	0.001	0.000
Item	Military	NS	4	0.214	0.054
Part	Military	GM	1	20.980	20.980
Part	Military	GF	30	527.640	17.588
Part	COTS	GM	6	1.070	0.178
Part	COTS	GF	8	1.070	0.134
Thing	Military	GF	0	0.004	inf.
Thing	Military	GM	11	2.590	0.235
Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Thing provides data for GF, GM, AUF, AIC, SF

However in GF it was run for a very short time

Without a long enough runtime to base data on, consider removing from the analysis

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
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Gadget	Military	AUF	7	32.200	4.600
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Thing	Military	AUF	7	13.900	1.986
Thing	Military	AUF	3	64.950	21.650
Thing	Military	AIC	2	0.438	0.219
Thing	Military	SF	5	3.930	0.786
Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

Widget provides data for COTS grade but not military

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
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Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

NOTIONAL DATA

All of the entries that provide conversions for AUF to SF can now be combined to create a generalized conversion ratio

With enough data across diverse parts, build a full table of generalized conversion factors

Description	Quality	Environment	Failed	Hours	Failure Rate
Component	COTS	AUC	10	232.150	23.215
Component	Military	AUF	3	0.046	0.015
Fidget	COTS	GF	1	12.990	12.990
Fidget	COTS	AUF	1	13.100	13.100
Fidget	COTS	SF	5	17.900	3.580
Gadget	Military	AUF	4	12.400	3.100
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Gadget	Military	AUF	7	24.860	3.551
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Widget	COTS	NS	30	78.460	2.615
Widget	COTS	GM	7	32.950	4.707
Widget	Military	GM	3	0.077	0.026

ANALYSIS OUTPUTS

- Examine constituent real world data
- Review statistics and limitations
- Present results

EXAMINE CONSTITUENT REAL WORLD DATA

Total Part-Hours included
12,785,395,142,948

	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
	Total component types considered					Electric		Mech.			
	247					162		85			
	Constituent Failure Rates										
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
n# rates	35	140	89	75	56	68	75	115	75	17	745

- 247 part types were included in the analysis
- Not enough Mech. For a mech-only table, however it does support an "all parts" table
- # factors in each environment pair

Constituent Factors

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0	16	14	8	0	4	8	6	9	0	0
GF	16	0	48	47	0	42	41	33	60	48	13
GM	14	48	0	36	0	14	19	9	27	33	9
NS	8	47	36	0	0	21	26	14	32	30	9
NU	0	0	0	0	0	0	0	0	0	0	0
AIC	4	42	14	21	0	0	23	18	25	16	4
AIF	8	41	19	26	0	23	0	26	47	14	5
AUC	6	33	9	14	0	18	26	0	57	7	0
AUF	9	60	27	32	0	25	47	57	0	29	3
ARW	0	48	33	30	0	16	14	7	29	0	13
SF	0	13	9	9	0	4	5	0	3	13	0

REVIEW STATISTICS AND LIMITATIONS

- No useful data in NU. Limited in SF, GB
- ML and MF data not gathered
- Variability in factors is concerning
- Meta-study with a high # of part hours

 # Constituent Factors

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0	16	14	8	0	4	8	6	9	0	0
GF	16	0	48	47	0	42	41	33	60	48	13
GM	14	48	0	36	0	14	19	9	27	33	9
NS	8	47	36	0	0	21	26	14	32	30	9
NU	0	0	0	0	0	0	0	0	0	0	0
AIC	4	42	14	21	0	0	23	18	25	16	4
AIF	8	41	19	26	0	23	0	26	47	14	5
AUC	6	33	9	14	0	18	26	0	57	7	0
AUF	9	60	27	32	0	25	47	57	0	29	3
ARW	0	48	33	30	0	16	14	7	29	0	13
SF	0	13	9	9	0	4	5	0	3	13	0

PARTS DISTRIBUTION IN THIS ANALYSIS

1. Hydraulic Accumulators, Fittings, Lines, Gauges, Pumps, Seals, Tanks, Valves – 13%
2. Batteries, Power Supply and Transmission, Transformers, Circuit Breakers, Capacitors, Inductors – 6%
3. Transistors, Crystals, Diodes, Cards and ICs, PCBs, Filters, Resistors – 38%
4. Fasteners and Hardware – 4%
5. Generators, Motors, Actuators – 5%
6. Sensors, meters, gauges, relays, switches – 23%
7. Other – 11%

COMPARE TO MIL-HDBK-217

1. Transistors – 2%
2. Capacitors – 28%
3. Resistors – 27%
4. ICs – 18%
5. Inductors – 17%
6. Diodes – 5%
7. Other – 3%

- MIL-HDBK-217 only used data on electrical parts and scoped its use to those part types
- Analysis in this presentation is built on more diverse electric parts, adds non-electrics

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered				Electric		Mech.				
	247				162		85				
	Constituent Failure Rates										
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
n# rates	35	140	89	75	56	68	75	115	75	17	745

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
n# factors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

Total component types considered	Electric	Mech.
247	162	85

How many of the parts were operated in the listed pair of environments

Constituent Failure Rates										
GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
35	140	89	75	56	68	75	115	75	17	745

Conversions

	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
n# factors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered				Electric		Mech.			
	247				162		85			
	Constituent Failure Rates									
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
	35	140	89	75	56	68	75	115	75	17	745

Median of the observed conversion factors

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
n# factors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

Total component types considered	Electric	Mech.
247	162	85

Constituent Failure Rates										
GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
35	140	89	75	56	68	75	115	75	17	745

Conversions

	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
factors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

Average of all observed conversion factors

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered					Electric		Mech.			
	247					162		85			
	Constituent Failure Rates										
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
	35	140	89	75	56	68	75	115	75	17	745

Average of all observed conversion factors, without outliers – this will go in the new table

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
...ors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
...med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
...tor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered	Electric	Mech.
	247	162	85

	Constituent Failure Rates									
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
	35	140	89	75	56	68	75	115	75	17	745

MIL-HDBK-217 factor

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
...tors		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
... med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
...tor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered				Electric		Mech.			
	247				162		85			
	Constituent Failure Rates									
	GB	GF	GM	NS	AIC	AIF	AUC	AUF	ARW	SF	Total
	35	140	89	75	56	68	75	115	75	17	745

Limitation: No data on parts operated in GB-SF pair

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC	SF to AIF	SF to AUC	SF to AUF	SF to ARW
		13.0000	9.0000	9.0000	4.0000	5.0000		3.0000	13.0000
med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered					Electric		Mech.			
	247					162		85			
	Constituent Fai										
	GB	GF	GM	NS	AIC	AIF			W	SF	Total
n# rates	35	140	89	75	56	68			5	17	745

No outliers means that the relatively few data points all agree with each other

	Conversions								
	SF to GB	SF to GF	SF to GM	SF to NS	SF to AIC			SF to AUF	SF to ARW
n# factors		13.0000	9.0000	9.0000	4.0000	.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.058	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

RESULTS

Total Part-Hours included
12,785,395,142,948

	Total component types considered					Electric		Mech.			
	247					162		85			
							Rates				
	GB	GF	GM	NS	[illegible]	[illegible]	[illegible]	AUF	ARW	SF	Total
n# rates	35	140	89	75	[illegible]	[illegible]	[illegible]	115	75	17	745

SF to GM has more variability, converges when removing outliers

	Conversions								
	SF to GB	SF to GF	SF to GM	[illegible]	[illegible]	SF to AIF	SF to AUC	SF to AUF	SF to ARW
n# factors		13.0000	9.0000	[illegible]	4.0000	5.0000		3.0000	13.0000
factor med		0.3913	0.0441	0.0348	0.0587	0.0358		0.0072	0.0053
factor avg		0.7551	11.3916	0.2297	0.1642	0.0782		0.0195	0.0390
avg no outliers		**0.3686**	**0.2240**	**0.1512**	**0.1642**	**0.0295**		**0.0195**	**0.0123**
MIL-HDBK Value	**0.9000**	**0.5000**	**0.2000**	**0.3000**	**0.3000**	**0.2000**	**0.1000**	**0.1000**	**0.1000**

OUTLIERS

- This is a meta-study
- Assumption: reporting or methodology errors account for a large amount of the variance in observed conversion factors
- 20% highest and lowest factors trimmed from data

Percentage Difference All Parts, Outliers Included vs Discluded

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%										
GF	271867%	0%									
GM	408116%	5899083%	0%								
NS	393634%	741%	1482%	0%							
NU					0%						
AIC	0%	157686197%	184%	462%		0%					
AIF	10598324%	1127%	187%	9001%		192442%	0%				
AUC	-4%	323%	1027%	132%		25134%	21334%	0%			
AUF	1573500%	634%	3126%	440%		535540%	107798%	775%	0%		
ARW		307502%	346%	216%		2856%	1093%	95%	194%	0%	
SF		105%	4985%	52%		0%	165%		0%	219%	0%

OUTLIERS

- This is a meta-study
- Assumption: reporting or methodology errors account for a large amount of the variance in observed conversion factors
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Percentage Difference All Parts, Outliers Included vs Discluded

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%										
GF	271867%	0%									
GM	408116%	5899083%	0%								
NS	393634%	741%	1482%	0%							
NU					0%						
AIC	0%	157686197%	184%	462%		0%					
AIF	10598324%	1127%	187%	9001%		192442%	0%				
AUC	-4%	323%	1027%	132%		25134%	21334%	0%			
AUF	1573500%	634%	3126%	440%		535540%	107798%	775%	0%		
ARW		307502%	346%	216%		2856%	1093%	95%	194%	0%	
SF		105%	4985%	52%		0%	165%		0%	219%	0%

TABLE 10.3-3 Environmental Conversion Factors from MIL-HDBK-338B

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1.2
GF	1.9	1	0.4	0.6	0.3	0.6	0.4	0.2	0.1	0.2	2.2
GM	4.6	2.5	1	1.4	0.7	1.4	0.9	0.6	0.3	0.5	5.4
NS	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.8
NU	7.2	3.9	1.6	2.2	1	2.2	1.4	0.9	0.5	0.7	8.3
AIC	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.9
AIF	5	2.7	1.1	1.5	0.7	1.5	1	0.6	0.4	0.5	5.8
AUC	8.2	4.4	1.8	2.5	1.2	2.5	1.6	1	0.6	0.8	9.5
AUF	14.1	7.6	3.1	4.4	2	4.2	2.8	1.7	1	1.4	16.4
ARW	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	1	11.9
SF	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1

Trimmed Mean Conversion Factors from 50+ Years of Data (Electric Parts)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1	0.32146	63.9325	0.14877	0.15605	0.12799	0.35123	2.25813	0.33599	0.01239	1.7094
GF	3.11084	1	0.07959	0.91199	0.10381	0.52931	0.14132	1.76129	0.17588	0.01368	2.79552
GM	0.01564	12.5647	1	0.29372	0.0543	0.39219	0.10402	0.04958	0.00685	0.04227	4.11334
NS	6.72193	1.0965	3.40465	1	0.05888	0.29383	0.02539	0.78882	0.12544	0.01747	6.4885
NU	6.408	9.633	18.416	16.984	1	1.23457	0.17212	0.36075	0.07123	0.0903	15.3846
AIC	7.81295	1.88925	2.54975	3.40331	0.81	1	0.08929	0.66818	0.3318	0.06899	23.7132
AIF	2.84713	7.07592	9.61311	39.3929	5.81	11.1995	1	7.904	1.01259	0.08456	45.1789
AUC	0.44284	0.56777	20.1677	1.26772	2.772	1.49661	0.12652	1	0.4834	0.11162	15.3846
AUF	2.97628	5.68581	146.065	7.97209	14.04	3.01387	0.98757	2.06868	1	0.44542	167.276
ARW	80.682	73.1034	23.6554	57.2509	11.074	14.4953	11.8256	8.95904	2.24509	1	74.5617
SF	0.585	0.35772	0.24311	0.15412	0.065	0.04217	0.02213	0.065	0.00598	0.01341	1

TABLE 10.3-3 Environmental Conversion Factors from MIL-HDBK-338B

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.[illegible]	[illegible]	[illegible]
GF	1.9	1	0.4	0.6	0.3	0.6	0.4	0.2	0.[illegible]	[illegible]	[illegible]
GM	4.6	2.5	1	1.4	0.7	1.4	0.9	0.6	0.[illegible]	[illegible]	[illegible]
NS	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.8
NU	7.2	3.9	1.6	2.2	1	2.2	1.4	0.9	0.5	0.7	8.3
AIC	3.3	1.8	0.7	1	0.5	1	0.7	0.4	0.2	0.3	3.9
AIF	5	2.7	1.1	1.5	0.7	1.5	1	0.6	0.4	0.5	5.8
AUC	8.2	4.4	1.8	2.5	1.2	2.5	1.6	1	0.6	0.8	9.5
AUF	14.1	7.6	3.1	4.4	2	4.2	2.8	1.7	1	1.4	16.4
ARW	10.2	5.5	2.2	3.2	1.4	3.1	2.1	1.3	0.7	1	11.9
SF	0.9	0.5	0.2	0.3	0.1	0.3	0.2	0.1	0.1	0.1	1

Trimmed Mean Conversion Factors from 50+ Years of Data (Electric Parts)

	[illegible]	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
[illegible]	[illegible]	[illegible].32146	63.9325	0.14877	0.15605	0.12799	0.35123	2.25813	0.33599	0.01239	1.7094
[illegible]	[illegible]	1	0.07959	0.91199	0.10381	0.52931	0.14132	1.76129	0.17588	0.01368	2.79552
[illegible]	[illegible]	[illegible]2.5647	1	0.29372	0.0543	0.39219	0.10402	0.04958	0.00685	0.04227	4.11334
NS	[illegible]	1.0965	3.40465	1	0.05888	0.29383	0.02539	0.78882	0.12544	0.01747	6.4885
NU	6.408	9.633	18.416	16.984	1	1.23457	0.17212	0.36075	0.07123	0.0903	15.3846
AIC	7.81295	1.88925	2.54975	3.40331	0.81	1	0.08929	0.66818	0.3318	0.06899	23.7132
AIF	2.84713	7.07592	9.61311	39.3929	5.81	11.1995	1	7.904	1.01259	0.08456	45.1789
AUC	0.44284	0.56777	20.1677	1.26772	2.772	1.49661	0.12652	1	0.4834	0.11162	15.3846
AUF	2.97628	5.68581	146.065	7.97209	14.04	3.01387	0.98757	2.06868	1	0.44542	167.276
ARW	80.682	73.1034	23.6554	57.2509	11.074	14.4953	11.8256	8.95904	2.24509	1	74.5617
SF	0.585	0.35772	0.24311	0.15412	0.065	0.04217	0.02213	0.065	0.00598	0.01341	1

In environment pairs without data, the average error in the rest of that environment was applied to the HDBK value

RESULTS

- Percent difference between MIL-HDBK factors and results
- MAPE of 377%
- Suggests refined understanding of effect of environment on electrical parts

Color Scale
Green is Closer to MIL-HDBK Values
Red is further
No Observed Data, Calculated from Mean error in Environment
Reciprocal, calculated from left hand of table

Percentage Error Between Tables (Electric Only)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%	-36%	31866%	-50%	56%	-57%	76%	2158%	236%	-88%	42%
GF	64%	0%	-80%	52%	-65%	-12%	-65%	781%	76%	-93%	27%
GM	-100%	403%	0%	-79%	-92%	-72%	-88%	-92%	-98%	-92%	-24%
NS	104%	-39%	386%	0%	-88%	-71%	-96%	97%	-37%	-94%	71%
NU	-11%	147%	1051%	672%	0%	-44%	-88%	-60%	-86%	-87%	85%
AIC	137%	5%	264%	240%	62%	0%	-87%	67%	66%	-77%	508%
AIF	-43%	162%	774%	2526%	730%	647%	0%	1217%	153%	-83%	679%
AUC	-95%	-87%	1020%	-49%	131%	-40%	-92%	0%	-19%	-86%	62%
AUF	-79%	-25%	4612%	81%	602%	-28%	-65%	22%	0%	-68%	920%
ARW	691%	1229%	975%	1689%	691%	368%	463%	589%	221%	0%	527%
SF	-35%	-28%	22%	-49%	-35%	-86%	-89%	-35%	-94%	-87%	0%

RESULTS

- Results represent an especially improved understanding of GM, AIF, and ARW environments

- Best to present in fractional form or lower triangular matrix only, to preserve commutability

Absolute Percentage Error Between Tables (Electric Only)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%	-36%	31866%	-50%	56%	-57%	76%	2158%	236%	-88%	42%
GF	64%	0%	-80%	52%	-65%	-12%	-65%	781%	76%	-93%	27%
GM	-100%	403%	0%	-79%	-92%	-72%	-88%	-92%	-98%	-92%	-24%
NS	104%	-39%	386%	0%	-88%	-71%	-96%	97%	-37%	-94%	71%
NU	-11%	147%	1051%	672%	0%	-44%	-88%	-60%	-86%	-87%	85%
AIC	137%	5%	264%	240%	62%	0%	-87%	67%	66%	-77%	508%
AIF	-43%	162%	774%	2526%	730%	647%	0%	1217%	153%	-83%	679%
AUC	-95%	-87%	1020%	-49%	131%	-40%	-92%	0%	-19%	-86%	62%
AUF	-79%	-25%	4612%	81%	602%	-28%	-65%	22%	0%	-68%	920%
ARW	691%	1229%	975%	1689%	691%	368%	463%	589%	221%	0%	527%
SF	-35%	-28%	22%	-49%	-35%	-86%	-89%	-35%	-94%	-87%	0%

ADDING NONELECTRICS

- Darker shading on the lower side of table indicates higher contribution from adding mechanical parts
- Lighter areas are where there was not observed data from mechanical parts. This is where further study will help most
- Not enough data to create a table for mechanical parts only
- Can however inform an “all parts” table

Contribution of Mechnical Parts to ALL PARTS Table

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	0%	-53%	-43%	-44%	-29%	0%	-17%	0%	-47%	32%	0%
GF	115%	0%	123%	-29%	-25%	-61%	-23%	-36%	-15%	39%	-3%
GM	76%	55%	0%	16%	-22%	23%	8%	76%	1211%	35%	9%
NS	79%	41%	14%	0%	-8%	1%	80%	5%	34%	174%	2%
NU	40%	34%	29%	8%	0%	-11%	-10%	-12%	-25%	-36%	0%
AIC	0%	158%	18%	1%	13%	0%	18%	50%	4%	-14%	-74%
AIF	20%	30%	8%	45%	11%	15%	0%	0%	-17%	51%	-25%
AUC	0%	56%	43%	5%	13%	33%	0%	0%	-2%	-28%	0%
AUF	88%	18%	92%	25%	32%	4%	20%	2%	0%	-46%	-69%
ARW	25%	28%	26%	64%	57%	16%	34%	39%	84%	0%	9%
SF	0%	3%	8%	2%	0%	289%	33%	0%	226%	9%	0%

Trimmed Mean Conversion Factors from 50 Years of Data (All Parts)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1										
GF	6.6829	1									
GM	0.0275	5.6298	1								
NS	12.005	1.5407	2.9268	1							
NU	773.58	-53.53	335.77	597.25	1						
AIC	7.8129	4.879	2.0796	3.37	-35.16	1					
AIF	3.4297	9.1878	8.8854	21.829	-65.89	9.4962	1				
AUC	0.4428	0.8867	11.449	1.2075	4.5203	1.0001	0.1265	1			
AUF	5.6048	6.686	11.141	5.9471	-177.1	2.9038	1.1849	2.1074	1		
ARW	60.894	52.643	17.587	20.892	-123.8	16.874	7.8393	12.458	4.1372	1	
SF	0.585	0.3686	0.224	0.1512	3948.7	0.1642	0.0295	0.065	0.0195	0.0123	1

Trimmed Mean Conversion Factors from 50 Years of Data (Electric Parts)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1										
GF	3.1108	1									
GM	0.0156	12.565	1								
NS	6.7219	1.0965	3.4046	1							
NU	6.408	9.633	18.416	16.984	1						
AIC	7.8129	1.8892	2.5498	3.4033	0.81	1					
AIF	2.8471	7.0759	9.6131	39.393	5.81	11.2	1				
AUC	0.4428	0.5678	20.168	1.2677	2.772	1.4966	0.1265	1			
AUF	2.9763	5.6858	146.06	7.9721	14.04	3.0139	0.9876	2.0687	1		
ARW	80.682	73.103	23.655	57.251	11.074	14.495	11.826	8.959	2.2451	1	
SF	0.585	0.3577	0.2431	0.1541	0.065	0.0422	0.0221	0.065	0.006	0.0134	1

CONCLUSIONS

ENV	Pleasantness
SF	35.66058649
GM	28.81265072
NS	12.77794475
GF	11.22954855
GB	11.16026079
NU	3.49440443
AIC	3.28253825
AUC	2.488345955
AIF	1.384516961
AUF	0.479423305
ARW	0.09001131

- "Pleasantness" is the average factor when converting TO the environment
- High numbers are more benign (MTBF increases = less failures per unit time)
- General ranking of severity of each environment

CONCLUSIONS

ENV	Pleasantness
SF	35.66058649
GM	28.81265072
NS	12.77794475
GF	11.22954855
GB	11.16026079
NU	3.49440443
AIC	3.28253825
AUC	2.488345955
AIF	1.384516961
AUF	0.479423305
ARW	0.09001131

- Surprising result – GF and GB are expected to be lower. May indicate a lack of understanding or uniform application of the environment. In GB there is a known limitation of relatively little data.

CONCLUSIONS

ENV	Pleasantness
SF	35.66058649
GM	28.81265072
NS	12.77794475
GF	11.22954855
GB	11.16026079
NU	3.49440443
AIC	3.28253825
AUC	2.488345955
AIF	1.384516961
AUF	0.479423305
ARW	0.09001131

- Otherwise results conform to common understanding – Aircraft are worst, with fighter worse than cargo and unmanned worse than manned. Rotary wing is worst of all.
- Naval unsheltered about 4 times worse than naval sheltered

CONCLUSIONS

- Original methods may have been well founded but suffered from limited data, lack of precision in conversion factors

- Adding 50+ years of field data gives better estimates – however even with much more data and removing outliers, we still see unexpected and uncertain results

- New look at "All Parts" conversion factor is possible and preferable to using the "electrics only table" – but not enough data to support using this technique in all cases

- With directed testing or gathering reported data, drastic improvements in conversion factors can be made.

- In environmental conversion, *nothing beats specific part data*. These tables are built on aggregates and meta studies that generalize. <u>Best case would be a table for each part type</u>.

- These tables are best used as *estimates*, and only *in standard environments*

FURTHER QUESTIONS

- Is a highly accurate environmental conversion table a necessity for today's engineers?
- Can similar analysis can be performed to improve on parts grade and perhaps temperature conversion factors
- Can data for ML and MF be re-incorporated into standard environments
- After peer review, can an update to MIL-HDBK-338 methods be widely communicated across the profession

RESULTS SUMMARY AND QUESTIONS

Trimmed Mean Conversion Factors from 50 Years of Data (All Parts)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1										
GF	6.6829	1									
GM	0.0275	5.6298	1								
NS	12.005	1.5407	2.9268	1							
NU	773.58	-53.53	335.77	597.25	1						
AIC	7.8129	4.879	2.0796	3.37	-35.16	1					
AIF	3.4297	9.1878	8.8854	21.829	-65.89	9.4962	1				
AUC	0.4428	0.8867	11.449	1.2075	4.5203	1.0001	0.1265	1			
AUF	5.6048	6.686	11.141	5.9471	-177.1	2.9038	1.1849	2.1074	1		
ARW	60.894	52.643	17.587	20.892	-123.8	16.874	7.8393	12.458	4.1372	1	
SF	0.585	0.3686	0.224	0.1512	3948.7	0.1642	0.0295	0.065	0.0195	0.0123	1

Trimmed Mean Conversion Factors from 50 Years of Data (Electric Parts)

	GB	GF	GM	NS	NU	AIC	AIF	AUC	AUF	ARW	SF
GB	1										
GF	3.1108	1									
GM	0.0156	12.565	1								
NS	6.7219	1.0965	3.4046	1							
NU	6.408	9.633	18.416	16.984	1						
AIC	7.8129	1.8892	2.5498	3.4033	0.81	1					
AIF	2.8471	7.0759	9.6131	39.393	5.81	11.2	1				
AUC	0.4428	0.5678	20.168	1.2677	2.772	1.4966	0.1265	1			
AUF	2.9763	5.6858	146.06	7.9721	14.04	3.0139	0.9876	2.0687	1		
ARW	80.682	73.103	23.655	57.251	11.074	14.495	11.826	8.959	2.2451	1	
SF	0.585	0.3577	0.2431	0.1541	0.065	0.0422	0.0221	0.065	0.006	0.0134	1

REFERENCES

- *Frank Hark and Steven Novack*, 2017 "MIL-HDBK-338 Environmental Conversion Table Correction"
- MIL-HDBK-217 and -338B, *DoD*
- Nonelectronic Parts Reliability Data Publication (NPRD-2016) – Quanterion Solutions Incorporated

BACKUP – GRADE CONVERSION

Following the dissolution of a military-grade widget supplier, your project requires you to find a new source for the Particular Widget *they had been producing. A candidate supplier, Cost Savers LLC, produces a* Particular Widget *at commercial-grade. How can you quantify the effect that this supplier substitution will have on the program's overall reliability?*