# DATA-INFORMED ENVIRONMENTAL CONVERSION

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

PREPARED FOR RAMS TRAINING SUMMIT XIV

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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:*

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

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

| Environment | FPMH |
|---|---|
| GF | 1 |
| GM | 1.5 |
| AUF | 5 |
| SF | .75 |

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

# 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

- 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

- 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

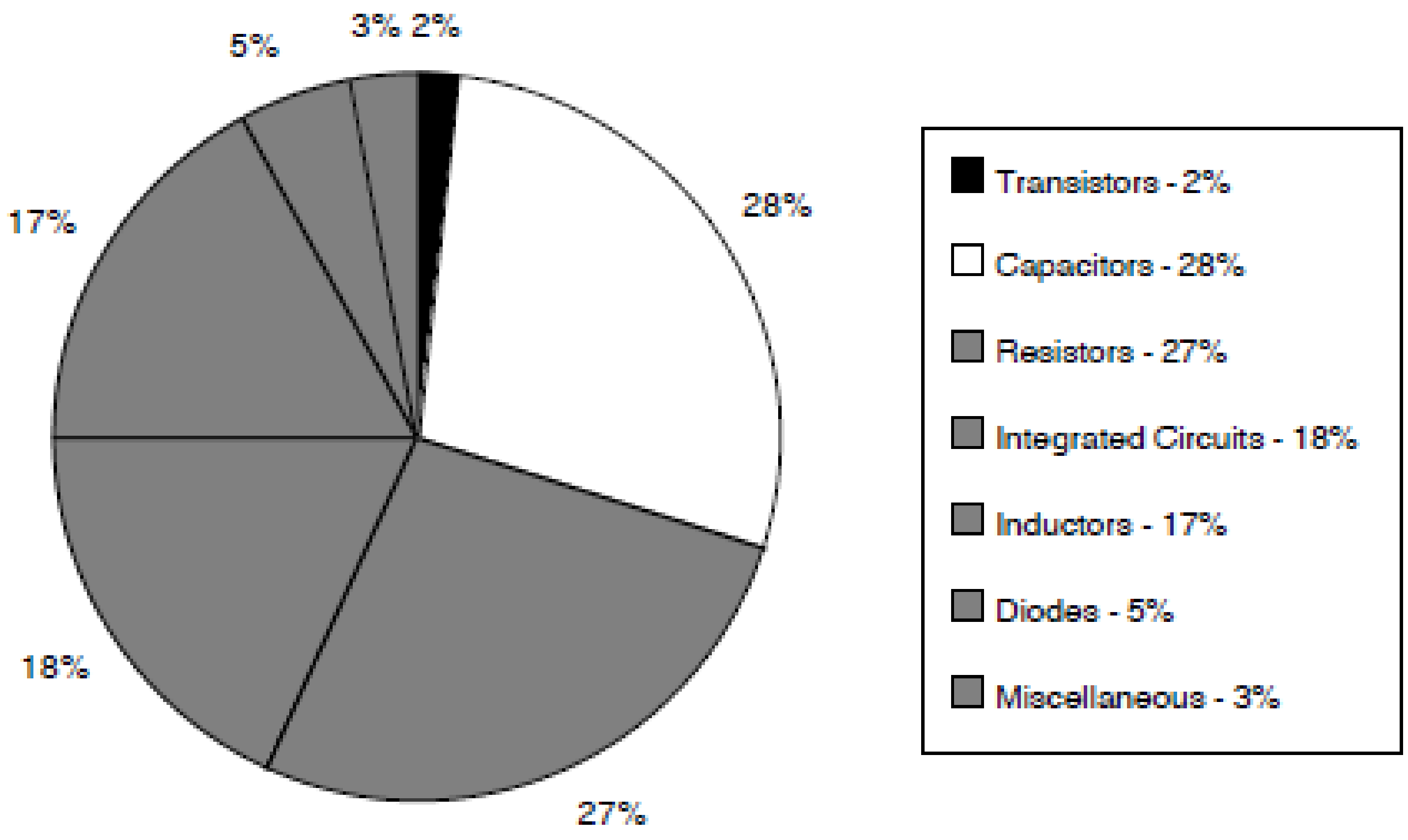


FIGURE 10.3-1: PART DATABASE DISTRIBUTION

# 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 |
| 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

*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 |
| 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

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 |
| 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 |

# 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 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 |

| 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 |

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

| 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 |

**Average of all 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 |
| 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 |

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 |

| | 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 |

**MIL-HDBK-217 factor**

# 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 |
|---|---|---|---|---|---|---|---|---|---|
| | | 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** |

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

# RESULTS

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

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

| | Conversions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | SF to GB | SF to GF | SF to GM | SF to NS | SF to AIC | [illegible] | [illegible] | SF to AUF | SF to ARW |
| n# factors | | 13.0000 | 9.0000 | 9.0000 | 4.0000 | [illegible]0000 | | 3.0000 | 13.0000 |
| factor med | | 0.3913 | 0.0441 | 0.0348 | 0.058[illegible] | 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** |

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

# RESULTS

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

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total component types considered | | | | | Electric | | Mech. | | | |
| | 247 | | | | | 162 | | 85 | | | |
| | | | | | | | | | | | |
| | | | | | | | Rates | | | | |
| | GB | GF | GM | NS | | | UC | AUF | ARW | SF | Total |
| n# rates | 35 | 140 | 89 | 75 | | | [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 | | | 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
- 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% |

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 | [illegible] | [illegible] | [illegible] |
| GF | 1.9 | 1 | 0.4 | 0.6 | 0.3 | 0.6 | 0.4 | 0.2 | [illegible] | [illegible] | [illegible] |
| GM | 4.6 | 2.5 | 1 | 1.4 | 0.7 | 1.4 | 0.9 | 0.6 | [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] | 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] | 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

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% |

| | |
|---|---|
| (green) | Color Scale<br>Green is Closer to MIL-HDBK Values |
| (white) | |
| (red) | Red is further |
| (gray) | No Observed Data, Calculated from Mean error in Environment |
| (blue) | Reciprocal, calculated from left hand of table |

# 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 form 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 |
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| AIF | 1.384516961 |
| AUF | 0.479423305 |
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- 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 |
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| 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 70+ 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. Best case would be a table for each part type.
- 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 | | | | | | | |
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| 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?*