FIDES MEANS FAITH IN LATIN

“TO INCREASE CONFIDENCE IN RELIABILITY PREDICTION”
FIDES HISTORY
WHY DGA REQUIRED A NEW RELIABILITY EVALUATION GUIDE?

- Electronic technologies, existing prediction guides are inadequate and now obsolete
  - Last IEC62380 issue is 2003 (RDF2000)
    - Being merged with IEC61709
  - Last MIL HDBK 217 issue is 1995
  - French Defense industry used MIL HDBK 217F with corrections factors but « tuning » was less and less effective
  - No COTS prediction
  - PRISM®/217Plus® not adapted to complex mission profiles and rugged environments

<table>
<thead>
<tr>
<th>Military equipment</th>
<th>MIL HDBK 217F (Pfi Q=10)</th>
<th>MIL HDBK 217F with correction</th>
<th>PRISM (217plus)</th>
<th>Field return</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTBF (in hours)</td>
<td>3063</td>
<td>19036</td>
<td>59673</td>
<td>169895</td>
</tr>
</tbody>
</table>
WHAT IS FIDES?

- Result of a study which began in 2001 on the aegis of the French MoD and developed by 8 companies
- Methodology for electronic systems reliability
- Based on **Physics of Failure (PoF)**
- Allows to take into account present processes from component selection to assembled board integration

- Answer to 2 strong needs
  - To make **realistic** reliability predictions
  - To **build** reliability without undergoing result
FIDES METHODOLOGY
Aims of FIDES
- Realistic prediction
- Usable for reliability assessment and building
- Usable for all kind of items, including COTS sub-assemblies
**GENERAL RELIABILITY MODEL**

\[ \lambda = \lambda_{\text{Physical}} \cdot \prod_{\text{PM}} \cdot \prod_{\text{Process}} \]

\[ \lambda_{\text{Physical}} = \left[ \sum_{\text{Physical Contributions}} (\lambda_0 \cdot \prod_{\text{acceleration}}) \right] \cdot \prod_{\text{induced}} \]

**Technology**

**Acceleration (normal stress)**
- \( \prod_{\text{Thermal}} \)
- \( \prod_{\text{Electrical}} \)
- \( \prod_{\text{Tcy : Temperature cycling}} \)
- \( \prod_{\text{Mechanical}} \)
- \( \prod_{\text{RH : Humidity}} \)
- \( \prod_{\text{Chemical}} \)

**Induced (overstress)**
- \( \prod_{\text{Placement}} \) : influence of the placement in the product, interfaces for instance
- \( \prod_{\text{Application}} \) : usage environment (vehicle, aircraft)
- \( \prod_{\text{Ruggedizing}} \) : overstress consideration in design
- \( \prod_{\text{Sensitivity}} \) : sensitivity to overstress of a technology

**Processes management (quality & Control)**
- Quality of manufacturer
- Quality of component
- Experience of supplier
We could not neglect about 70% of the failure root causes: process has to be taken into account = Πprocess audit check list (#250 questions)
### FIDES BASICS

#### ΠPart Manufacturing

- $\Pi_{PM}$ (from 0.5 to 2) component quality depending on
  - Quality assurance level
    - Manufacturer (QA_Manufacturer)

<table>
<thead>
<tr>
<th>Manufacturer quality assurance level</th>
<th>Position relative to the state of the art</th>
<th>QA_manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified ISO/TS16949 V2002</td>
<td>Higher</td>
<td>3</td>
</tr>
<tr>
<td>Certified according to one of the following standards: QS9000, TL9000, ISO/TS 29001, EN9100, AS9100, JISQ 9100, AQAP 2110, AQAP 2120, AQAP 2130, IRIS, IEC TS 62239, ESA/ECSS QPL, MIL-PRF-38535 QML, MIL-PRF-19500</td>
<td>Equivalent</td>
<td>2</td>
</tr>
<tr>
<td>ISO 9000 version 2000 certified</td>
<td>Lower</td>
<td>1</td>
</tr>
<tr>
<td>No information</td>
<td>Very much lower</td>
<td>0</td>
</tr>
</tbody>
</table>

- Component (QA_Component)

<table>
<thead>
<tr>
<th>Component quality assurance level</th>
<th>Position relative to the state of the art</th>
<th>QA_component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification according to one of the following standards: AEC-Q100, MIL-PRF-38535 class V, ESA ESCC 90xx, NASA-QTS-xxx class I, NPSL NASA level 1</td>
<td>Higher</td>
<td>3</td>
</tr>
<tr>
<td>Manufacturer qualification including tests conforming with standards JESD22, EIAJ-ED-4701, MIL-STD-883, IEC 68 with identification of &quot;front-end&quot; and &quot;back-end&quot; manufacturing sites; Qualification according to one of the following standards: MIL-PRF-38535 class Q, MIL-PRF-38535 class M, MIL-PRF-38535 class N, MIL-PRF-38535 class T, NASA-QTS-xxx class II, NPSL NASA level 2 &amp; 3, STACK-S0001</td>
<td>Equivalent</td>
<td>2</td>
</tr>
<tr>
<td>Qualification program internal to the manufacturer and unidentified manufacturing sites</td>
<td>Lower</td>
<td>1</td>
</tr>
<tr>
<td>No information</td>
<td>Much lower</td>
<td>0</td>
</tr>
</tbody>
</table>
### Component Reliability assurance level

- **RA_Component**

<table>
<thead>
<tr>
<th>Title of accelerated aging test</th>
<th>High Temperature Operating Life (HTOL)</th>
<th>Pre-conditioning before TC, THB or HAST</th>
<th>Temperature Cycling (TC)</th>
<th>Pressure Cooker Test (PCT)</th>
<th>Highly Accelerated Stressed Tests (HAST)</th>
<th>Temperature Humidity Biased (THB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference standards</td>
<td>EIA JESD-22-A108 A or equivalent</td>
<td>EIA JESD-22-A113A or equivalent</td>
<td>EIA JESD-22-A104 or equivalent</td>
<td>EIA JESD-22-A102 or equivalent</td>
<td>EIA JESD-22-A110 or equivalent</td>
<td>EIA JESD-22-A101 or equivalent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk</th>
<th>RA_Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- **Very reliable level A**
  - 1000h, 125°C, Vmax, 231/0 (1) 900/0
  - done
  - 1000 cycles - 55°C + 150°C or 500 cycles - 65°C + 150°C 231/0 or 1000 cycles -55°C/125°C 385/0
  - 168 h at 121°C / 100%RH 231/0
  - 168 h at 130°C/85%RH 231/0
  - 168 h at 130°C/85%RH 231/0

- **Very reliable level B**
  - 1000h, 125°C, Vmax, 154/0 (1) 900/0
  - done
  - 1000 cycles - 55°C + 125°C, 154/0
  - 96 h at 121°C / 100%RH, 154/0
  - 96 h at 130°C/85%RH, 154/0
  - 96 h at 130°C/85%RH, 154/0

- **Reliable**
  - 1000h, 125°C, Vmax, 77/0 (1) 231/0
  - done
  - 500 cycles - 65°C + 125°C 154/0
  - 96 h at 121°C / 100%RH, 77/0
  - 96 h at 130°C/85%RH, 77/0
  - 1000 h at 65°C/85%RH, 154/0

- **Not reliable**
  - Design below the reliable level
  - Not done
  - Design below the reliable level

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[Image and logo]
TECHNOLOGY
Physical contributors (IC model example)

\[ \lambda_{\text{Physical}} = \sum \left( \frac{\text{Phases} \times \text{Intensity}}{8760} \right) \left( \lambda_{\text{Therm}} + \lambda_{\text{Casing}} + \lambda_{\text{Acceleration}} + \lambda_{\text{Solder joints}} + \lambda_{\text{RH}} + \lambda_{\text{Mech}} \right) \]

- \( \lambda_0 \): basic failure rate for each stress
- \( \Pi_{\text{acceleration}} \): acceleration factor, sensitivity to rated physical contributors

<table>
<thead>
<tr>
<th>( \Pi_{\text{Thermal}} )</th>
<th>In an operating phase: ( e ) ( \times ) ( \left( \frac{11604 \times 0.7}{293} \right)^{\frac{1}{1}} \left( \frac{1}{(T_{\text{component}} + 273)} \right) ) ( \times ) ( e ) |</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a non-operating phase: ( \Pi_{\text{Thermal}} = 0 )</td>
<td></td>
</tr>
</tbody>
</table>

| \( \Pi_{\text{TCy Case}} \) | \( \left( \frac{12 \times \min(\theta_{\text{cy},2})}{2} \right)^{\frac{1}{2}} \left( \frac{\Delta T_{\text{cycling}}}{20} \right)^{\frac{1.5}{1}} \times \left( \frac{1}{(T_{\text{nuc-cycling}} + 273)} \right) \times e \) |

| \( \Pi_{\text{TCy Solder joints}} \) | \( \left( \frac{12 \times \min(\theta_{\text{cy},2})}{2} \right)^{\frac{1}{2}} \left( \frac{\Delta T_{\text{cycling}}}{20} \right)^{\frac{1.5}{1}} \times \left( \frac{1}{(T_{\text{nuc-cycling}} + 273)} \right) \times e \) |

| \( \Pi_{\text{Mech}} \) | \( \left( \frac{G_{\text{tan}}}{0.5} \right)^{\frac{1}{1.5}} \) |

| \( \Pi_{\text{RH}} \) | \( \left( \frac{11604 \times 0.9}{293} \right)^{\frac{1}{1}} \left( \frac{1}{(T_{\text{nuc-ambient}} + 273)} \right) \times e \) |

In an operating phase: \( \Pi_{\text{RH}} = 0 \)

Arrhenius
Norris-Landsberg
Basquin
Peck
COMPONENT MODELS

- **Model based on**
  - Manufacturer reliability tests exploitation

<table>
<thead>
<tr>
<th>Test</th>
<th>IC</th>
<th>Discrete</th>
<th>( \lambda_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTOL High Temperature Operating Life</td>
<td>( X )</td>
<td>( \Rightarrow \lambda_{0TH} )</td>
<td></td>
</tr>
<tr>
<td>HTGB High Temperature Gate Bias</td>
<td>( \Rightarrow \lambda_{0TH} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCT ou AC Pressure Cooker Test / Autoclave</td>
<td>( X )</td>
<td>( \Rightarrow \lambda_{0RH} )</td>
<td></td>
</tr>
<tr>
<td>TC / TS Temperature Cycle / Thermal Shock</td>
<td>( X )</td>
<td>( X )</td>
<td>( \Rightarrow \lambda_{0TC_case} )</td>
</tr>
</tbody>
</table>

- **Report on PCB qualification tests and simulation**
  - \( \lambda_{0TC\_solder\_joints} \)

- **Using standard acceleration laws**
  - Arrhenius (\( \Pi_{th} \)), modified Peck (\( \Pi_{RH} \)), Coffin-Manson (\( \Pi_{TC\_case} \)), Engelmayr&Norriz-Landzberg (\( \Pi_{TC\_solder\_joints} \)), modified IPC-SM785 (\( \Pi_{meca} \))
COMPONENT MODELS IN 2009 FIDES GUIDE

- Integrated circuits
- ASIC
- Discrete semiconductors
- LED
- Optocouplers
- Resistors
- Fuses
- Ceramic capacitors
- Aluminum capacitors
- Tantalum capacitors

- Magnetic components
- Piezoelectric components
- Monostable electromechanical relays
- Switches
- Printed circuit board
- Connectors
- Hybrids and Multi Chip Modules
- Hyper frequency (HF) and radiofrequency (RF) components

- Sub-assemblies:
  - LCD screens
  - CRT screens
  - Hard disks
  - AC/DC and DC/DC
  - Lithium and nickel batteries
  - Fans
  - Keyboards

COTS boards
- Part count
- Family count
- Lead free process

Parts
Boards
Sub-assemblies
# LIFE PROFILE

Example – Personal car

## Personal car - used daily

<table>
<thead>
<tr>
<th>Phase title</th>
<th>Calendar time (hours)</th>
<th>On/Off</th>
<th>Ambient temperature (°C)</th>
<th>ΔT</th>
<th>Number of cycles (°C/year)</th>
<th>Cycle duration (hours)</th>
<th>Maximum temperature during cycling (°C)</th>
<th>Relative humidity (%)</th>
<th>Random vibrations (Grms)</th>
<th>Mechanical</th>
<th>Chemical</th>
<th>Protection level</th>
<th>Application induced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking off</td>
<td>8212.5</td>
<td>Off</td>
<td>15</td>
<td>10</td>
<td>365</td>
<td>22.5</td>
<td>20</td>
<td>70</td>
<td>0</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Non hermetically sealed 3.1</td>
</tr>
<tr>
<td>Driving on road</td>
<td>365</td>
<td>On</td>
<td>35</td>
<td>20</td>
<td>730</td>
<td>0.5</td>
<td>35</td>
<td>22</td>
<td>1.4</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Non hermetically sealed 5.1</td>
</tr>
<tr>
<td>Traffic jam</td>
<td>182.5</td>
<td>On</td>
<td>50</td>
<td>15</td>
<td>730</td>
<td>0.25</td>
<td>50</td>
<td>10</td>
<td>1.6</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Non hermetically sealed 5.1</td>
</tr>
</tbody>
</table>

Total: 8 760
LIFE PROFILE INFLUENCE

Example – Recent electronic board assessment

- Base (PC like):
  - Thermal: 383 FIT
  - Thermal cycle: x 1.5
  - Mecanical: x 3.5
  - Humidity: x 2
  - Thermo-electrical: x 8.5
  - Chemical: x 3.5
  - Electrical: x 2

- Radio:
  - 568 FIT

- Main Battle Tank:
  - 696 FIT

- Helicopter:
  - 1333 FIT

- Fighter:
  - 3239 FIT
COMPARISON BETWEEN FIDES AND MIL HDBK 217F
« MILHDBK217 should not be used (nor extrapolated) beyond limitations identified in the table above »

« When a specific family is not covered by MILHDBK217, the methodology prepared in the present handbook should be used to choose the most appropriate alternative standard or handbook

<table>
<thead>
<tr>
<th>Component class</th>
<th>Component category</th>
<th>Component sub-category</th>
<th>MIL-217 para</th>
<th>MIL-217 para and limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>Integrated circuits</td>
<td>Logic devices</td>
<td>5.1</td>
<td>≤ 60 k gates ≥ 0,8 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear devices</td>
<td>5.1</td>
<td>≤ 10 k trans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microprocessors</td>
<td>5.1</td>
<td>≤ 32 bits ≥ 0,8 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Volatile memories</td>
<td>5.2</td>
<td>≤ 1 Mbit ≥ 0,8 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non–volatile memories</td>
<td>5.2</td>
<td>≤ 1 Mbit ≥ 0,8 μm</td>
</tr>
</tbody>
</table>
FIDES VERSUS MIL HDBK 217F

- News technology/component (μprocessor, memory, COTS board…) models in FIDES
- MIL HDBK 217 = operating failure rates
  FIDES = calendar failure rates (with detailed definition of dormant phases)
- Extrinsic failure rate considered in FIDES: $\Pi_{\text{Process}}$ and $\Pi_{\text{induced factors}}$
- FIDES: sensitive to quality considerations, from design to usage ($\Pi_{\text{PM}}, \Pi_{\text{Process}}$)
RELIABILITY ENGINEERING WITH FIDES RESULTS

- Failure distribution according to life profile

**Parts family contribution**
- Capacitor: 44%
- Resistor: 19%
- Integrated circuits: 18%
- Discrete semiconductor circuits: 3%
- Optocouplers: 1%
- Printed circuits: 5%
- Connectors: 2%
- Hermetically sealed electromechanical relays: 0%
- Piezoelectric parts: 8%
- Magnetic components: 0%

**Phases contribution**
- Driving on road: 54%
- Traffic jam: 38%
- Parking off: 8%

**Environmental contribution**
- Thermal: 67%
- Mechanical: 2%
- Chemical: 2%
- Electrical: 0%
- Thermal cycling: 10%
- Humidity: 2%
- Mechanical: 2%
- Chemical: 10%
- Electrical: 2%
- Thermal cycling: 17%
**FIDES VS FIELD RETURN**

- **REX** was French MoD study with 5 companies
  - 15 electronic systems
  - 24 millions electronic components
  - >2 years of observation

FIDES is generally closer to field return, more realistic and less pessimistic than MIL HDBK 217F.

<table>
<thead>
<tr>
<th>Equipement</th>
<th>MTBF REX/MIL</th>
<th>MTBF REX/FIDES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>51,8</td>
<td>3,3</td>
</tr>
<tr>
<td>2</td>
<td>10,1</td>
<td>1,1</td>
</tr>
<tr>
<td>3</td>
<td>6,7</td>
<td>0,9</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>4,2</td>
</tr>
<tr>
<td>5</td>
<td>2,8</td>
<td>1,0</td>
</tr>
<tr>
<td>6</td>
<td>0,6</td>
<td>0,5</td>
</tr>
<tr>
<td>Total</td>
<td>9,1</td>
<td>1,1</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4,8</td>
<td>1,2</td>
</tr>
<tr>
<td>8</td>
<td>17,6</td>
<td>4,5</td>
</tr>
<tr>
<td>Total</td>
<td>6,4</td>
<td>1,6</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>12,4</td>
<td>2,2</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3,1</td>
<td>0,7</td>
</tr>
<tr>
<td>11</td>
<td>3,2</td>
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<tr>
<td>Total</td>
<td>3,1</td>
<td>0,7</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2,5</td>
<td>1,3</td>
</tr>
<tr>
<td>13</td>
<td>1,4</td>
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<tr>
<td>14</td>
<td>1,3</td>
<td>0,3</td>
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<tr>
<td>15</td>
<td>0,5</td>
<td>0,2</td>
</tr>
<tr>
<td>Total</td>
<td>1,1</td>
<td>0,4</td>
</tr>
</tbody>
</table>
FIDES REVISION

- New DGA R&T study *PISTIS* (2015-2019)
  - DSM, HF power (GaN) and power (IGBT) components reliability
  - Are existing FIDES models adapted to these new technologies?
  - What about lifetime (wearout) of these technologies?
  - Fides models or parameters revision
    - $\lambda_0$ die and case
    - $\Pi_{process}$ audit
    - $\Pi_{induced}$ (EOS)
CONCLUSION 1/2

- Impossible to use and adapt obsolete MIL HDBK 217 for new designs
- FIDES takes into account overstresses, life profile (even for dormant applications)
- FIDES is able to improve reliability by contributors analysis and $\prod_{\text{Process}}$ audit check list
- Maintenance structure created to update FIDES methodology
  - www.fides-reliability.org
- FIDES has potential for evolution
CONCLUSION

- FIDES is a reference standard in DGA contracts since 2005 (missile, radio telecom, vehicle, fighter aircraft...)
- FIDES aims to cover all the industrial needs in matter of reliability, included space domain
- FIDES is used by several companies in Europe (Aeronautical, Defence, Automotive, Rail transportation, General purpose...)
- Need for an international reference
THANK YOU FOR YOUR ATTENTION