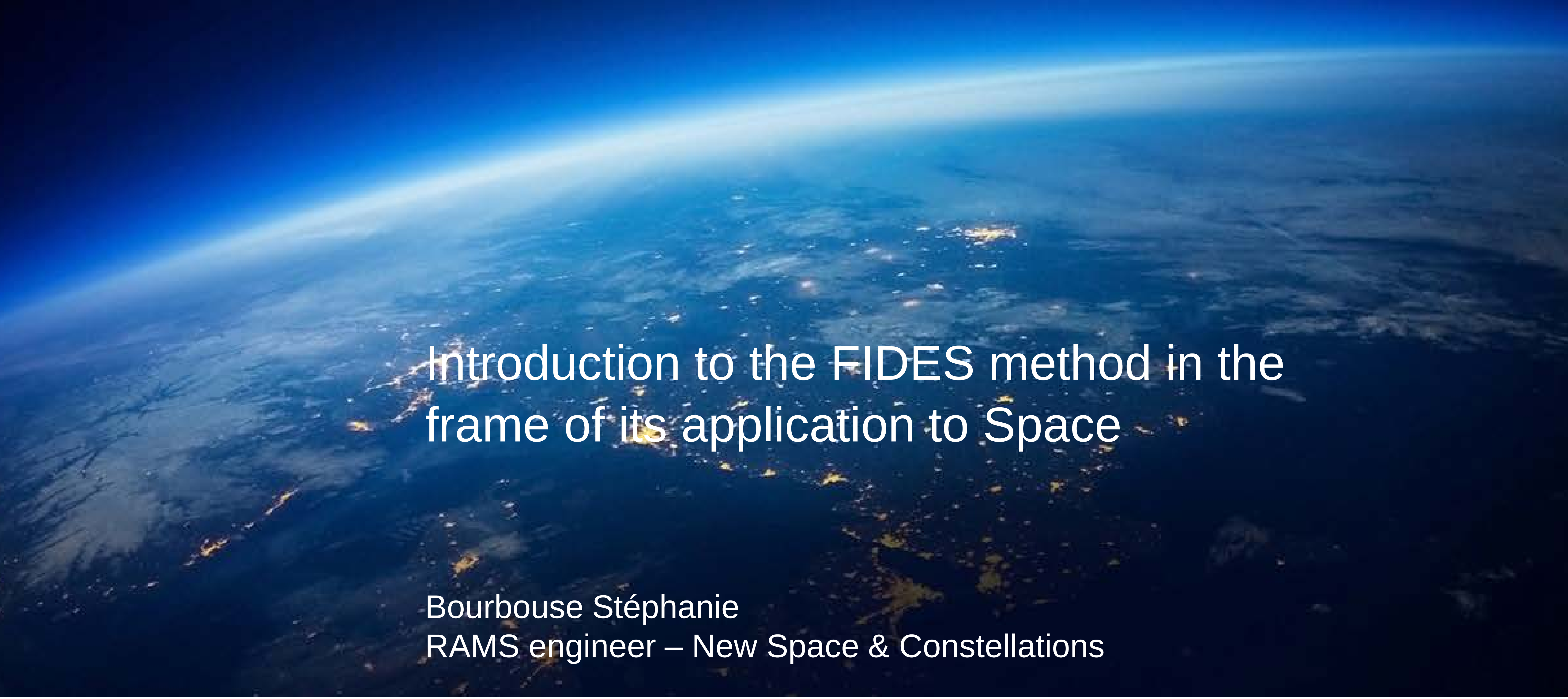

Introduction to the FIDES method in the frame of its application to Space

Bourbouse Stéphanie
RAMS engineer – New Space & Constellations

DEFENCE AND SPACE

TEIR department
June 19th 2019

AIRBUS

Introduction to the FIDES method in the frame of its application to Space

1. Context of reliability predictions for EEE parts in the European Space community

2. The FIDES method – reminder of what it is and why it is considered for Space applications

3. Evolutions since 2016, current situation and perspectives for FIDES

4. Updates on ADS and the European space community wrt FIDES

5. Ongoing actions and way forward

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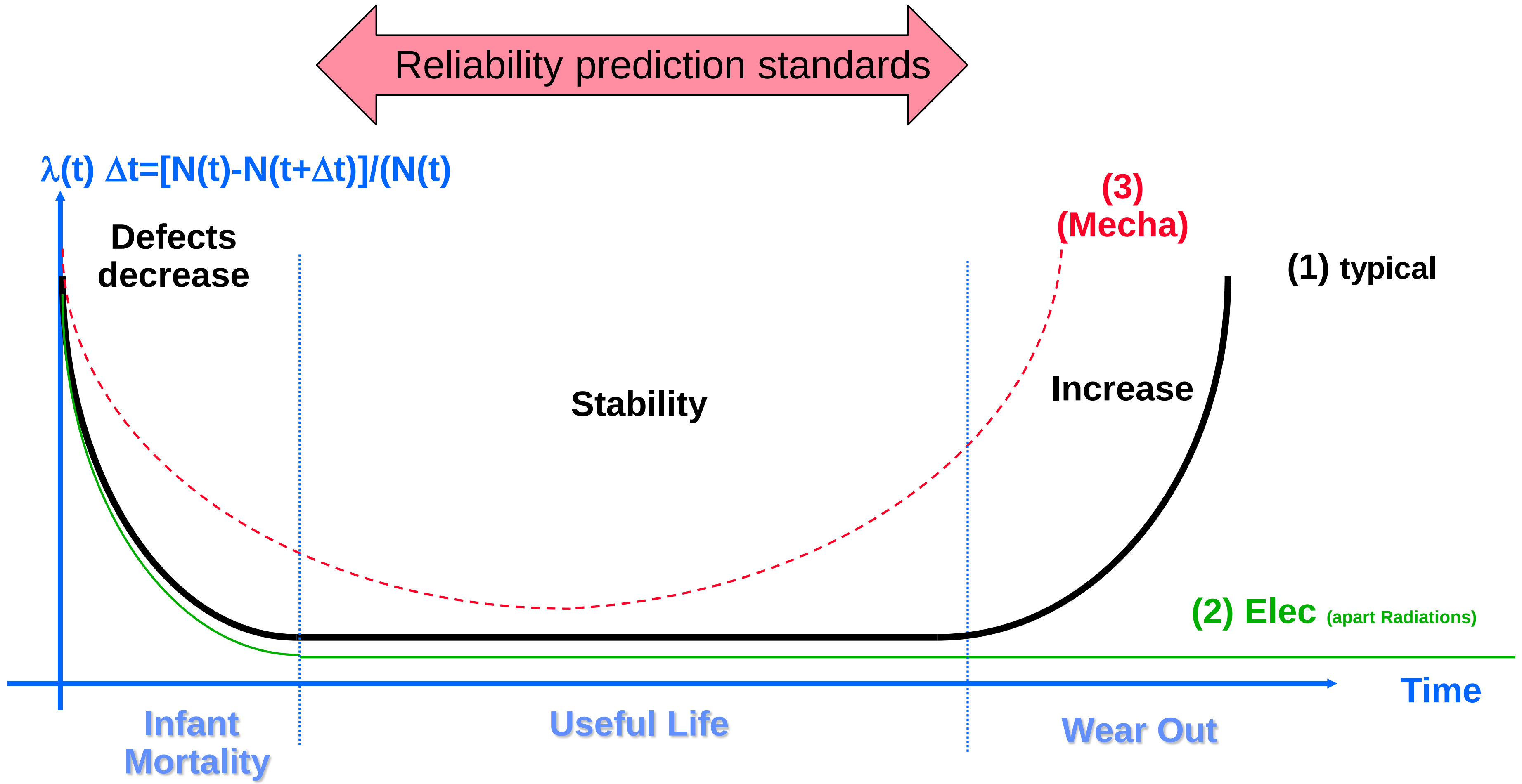

$$R(t) = P(\{T>t\}) = \exp^{-\int_0^t \lambda(u)du}$$

EXPONENTIAL Case : λ(t) = λ $\Longrightarrow$ $R(t) = \exp^{-\lambda t}$

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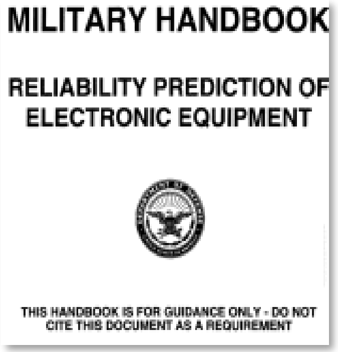
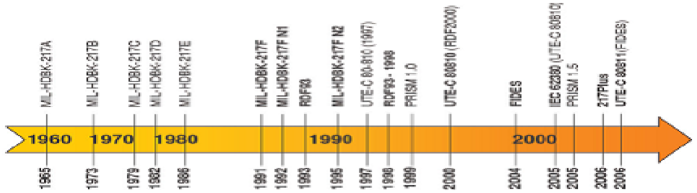
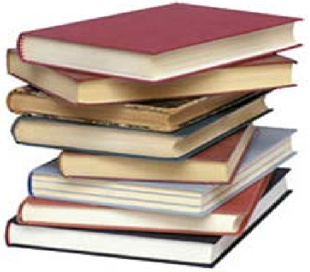
1. Context of reliability predictions for EEE parts in the European Space community

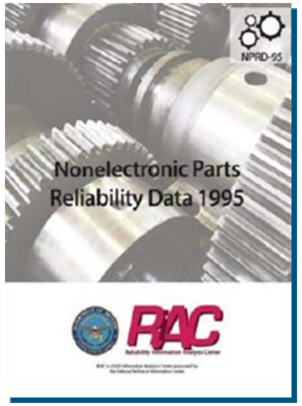
- <u>EEE Parts</u>
  - Mil-HDBK-217
  - RDF2000
  - FIDES





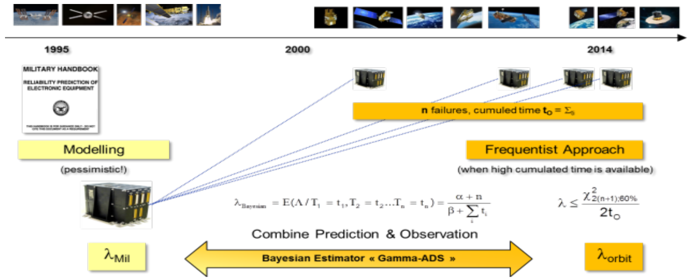


- <u>Mechanical Parts</u>
  - NPRD95 or 2011
  - NSWC 2011



- <u>Miscellaneous parts</u>
  - IN-HOUSE data (Experts assessment…)
  - RF passive parts, battery , propulsion items …

- <u>Specific estimate</u>
  - TEST limited to some specific parts/units
  - IN-ORBIT FEEDBACK for generic products (E3000…)



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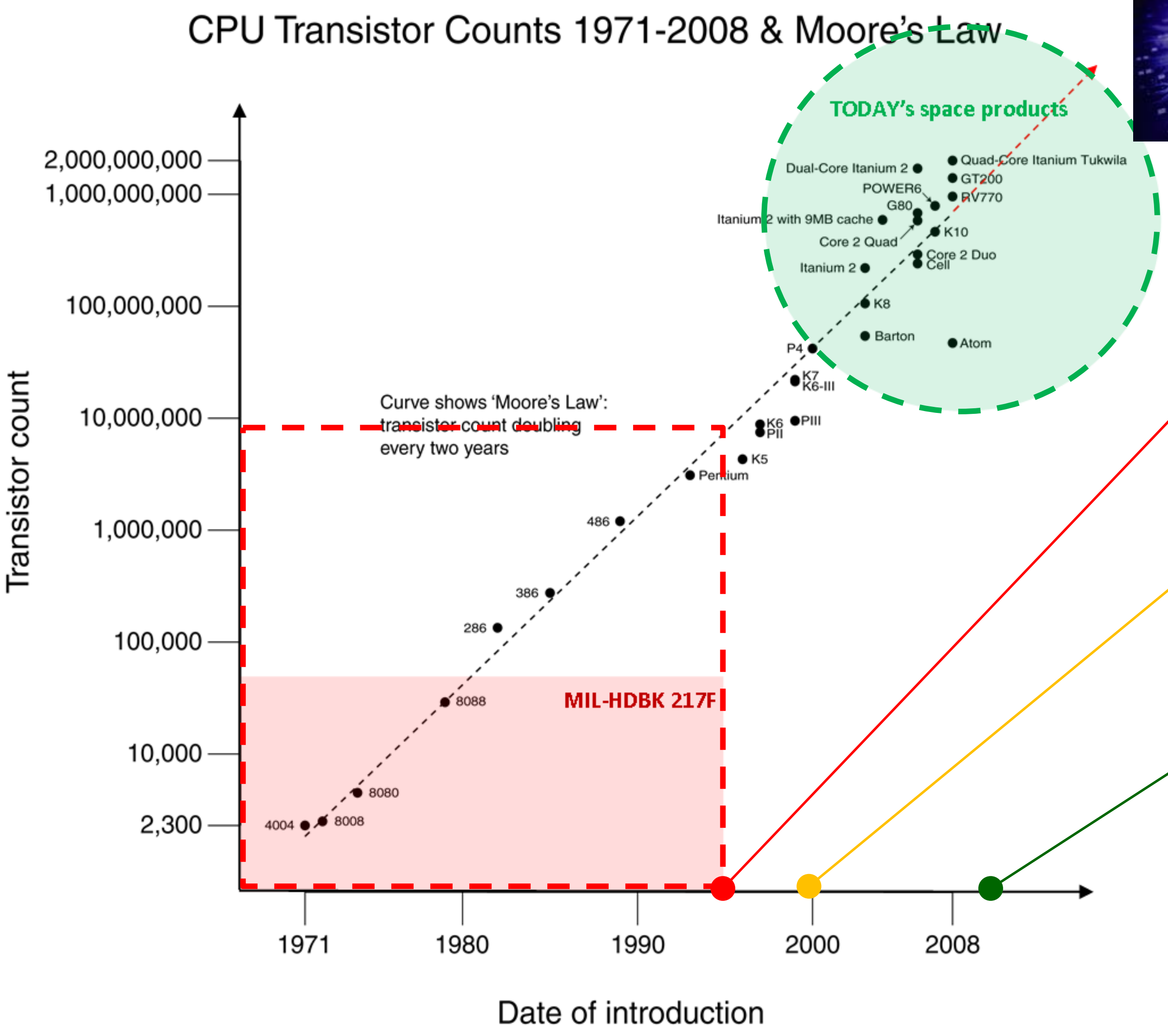
1. Context of reliability predictions for EEE parts in the European Space community



MIL-HDBK-217F

RDF2000
(UTE C80-810)

FIDES 2009
(UTE C80-811)

FIDES 2020
(PISTIS)

1. Context of reliability predictions for EEE parts in the European Space community

- Extract from ECSS-Q-HB-30-08A (2011) – Annex 1 – Potential data sources for EEE reliability predictions
- 10 Standards or handbooks, among which :

  - **MIL-HDBK-217**

- MIL-HDBK-217, Reliability Prediction of Electronic Equipment, has been the mainstay of reliability predictions for about 40 years.
- The handbook was published by the Department of Defense, Washington DC, U.S.A, and is available via several websites on the internet. Its last issue is the Rev. F + Notice 2.
- The handbook is incorporated within several commercially available reliability software packages.

  - **FIDES (UTE C 80-811)**

- FIDES is a new reliability data handbook (available since January 2004) developed by a consortium of French industry under the supervision of the French DoD (DGA).
- The FIDES methodology is based on physics of failures and is supported by the analysis of test data, field returns and existing modelling. It aims to enable a realistic assessment of electronic equipment reliability, including systems operating in severe environments (e.g. defense systems, aeronautics, industrial electronics, and transport).
- The FIDES guide is divided in two parts : a reliability prediction guide and a reliability process control and audit guide. By identifying the factors contributing to reliability, whether technological, physical or process-based, FIDES allows the revision of product definition and intervention throughout the product lifecycle, to improve and control reliability. FIDES is available on request at fides@innovation.net.

1. Context of reliability predictions for EEE parts in the E

Source	1-Suitability	2-Credibility	3-Usability	4-Perenniality	5-Cost
EEE Parts					
MIL-HDBK-217	-	-	++	- -	++
ANSI/VITA	-	-	+	-	+
GJB/z 299C	+	-	-		
217-Plus	+	+	+	+	-
RDF 2000	-	-	+	-	+
IRPH	-	-	-		
Siemens	-	+	+	-	+
FIDES	+	+	+	+	-
AMSAA					
AT&T					
CORDS					
EIReDA					
Harris					
HRD 5	-				
IEEE Gold Book	-	-	-		++
IEEE 1413					
NTT					
OREDA					
REMM					
SAE					
Sandia					
Telcordia	-	-	+	+	- -
TUD					
Mechanical Parts					
NPRD	+	+	++	+	
NSWC-11	+	+	++	-	++

- In 2016, the Reliability Prediction Data Sources and Methodology study, performed by Airbus Defence & Space (UK & France) for I the most adequate reliability prediction models & methods for spa

- Study performed in three steps for EEE components:
  - Step 1: Survey to determine the best candidates for EEE reliability prediction
  - Step 2: Comparison between the three candidates: MIL HDBK 217FN2, FIDES and 217PLUS
  - Step 3: Modelling of use case with FIDES to compare with with MIL prediction and In-Orbit Return based prediction.

Recommendation to use FIDES for new projects with adaptations for space

Introduction to the FIDES method in the frame of its application to Space

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2. The FIDES method – reminder of what it is and why it is considered for Space applications

- FIDES is the most recently developed reliability prediction calculation method for electronic systems based on physics of failures (PoF), field return (mainly military & aeronautics) & tests.

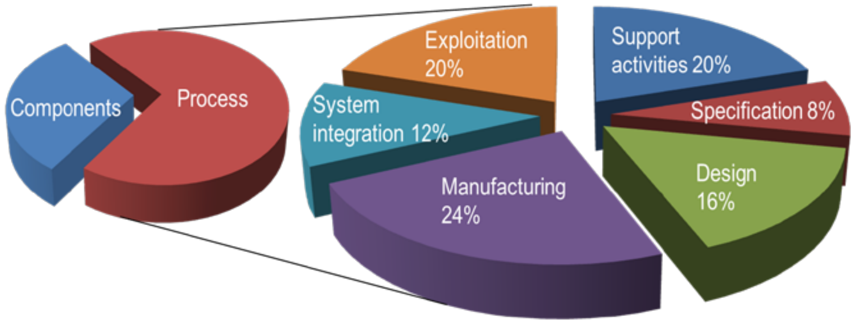
- It has been introduced in 2004 by a consortium of French industrials (led by DGA (French DoD) & MBDA, including Thales, Eurocopter, Airbus, Nexter), with an update in 2009

- Support structure = FIDES working group meeting 4 times each year

- Also known as the UTE C80811 standard – Soon an IEC standard (target = 2022)

- The standard is free of use, and a free tool (FIDES ExperTool) is available – downloadable at www.fides-reliability.org

2. The FIDES method – reminder of what it is and why it is considered for Space applications

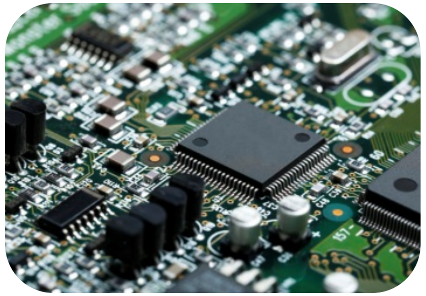


We could not neglect about 70% of the failure root causes : process has to be taken into account = Πprocess audit check list (#250 questions)

Technologies

Technological classification of components

Reliability

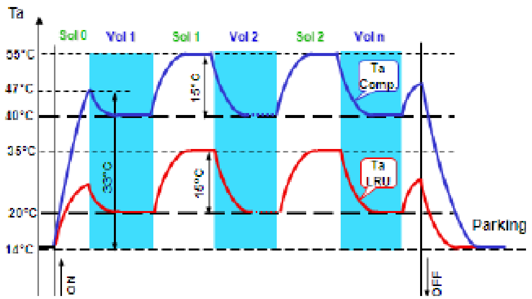


Impact of the industrial process
-
Audit on the life cycle of the product

Process

Use

Life cycle of the system



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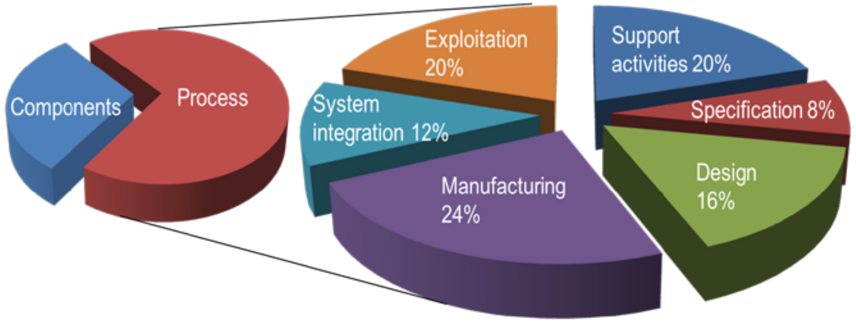
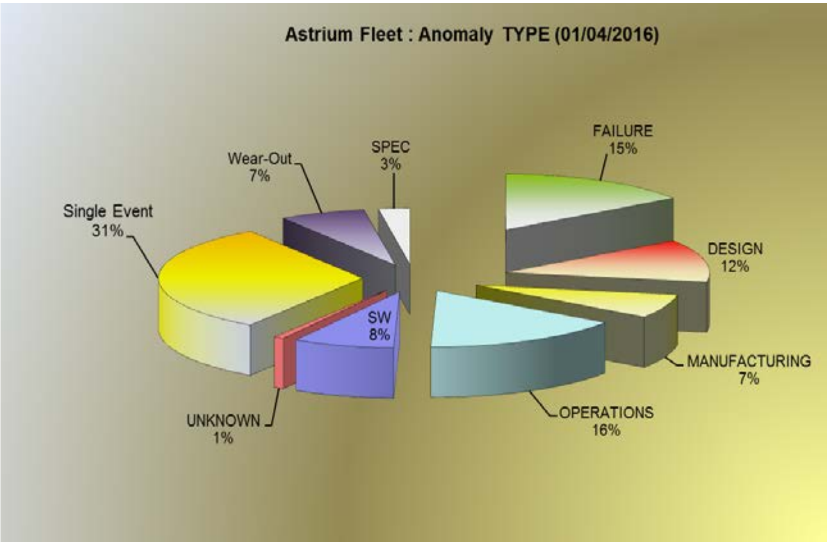
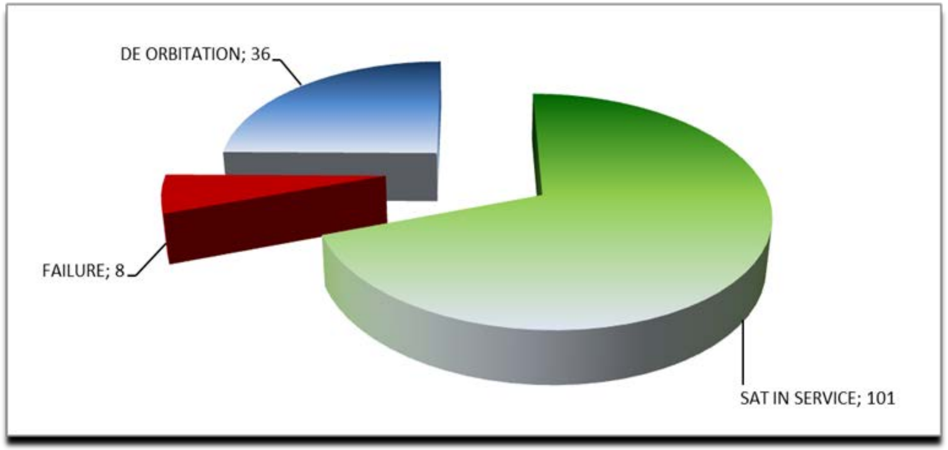


We could not neglect about 70% of the failure root causes : process has to be taken into account = Πprocess audit check list (#250 questions)

8 LOSSES	→ LTR (LifeTime Ratio)
• TELECOM 1B	0,38
• W2M	0.01 (50%)
• SPOT3	1,05
• SAT1B	1
• ENVISAT	2,02
• ROCSAT2	2,42
• ERS1	2,88
• ULYSSES	3.54





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2. The FIDES method – reminder of what it is and why it is considered for Space applications

- In the frame of the RPDSM study, the Failure Rate (FR) of the on-board computer of the platform of the E3000 telecom family have been calculated with both FIDES and MIL (same conditions – 20°C mean temperature). The results are:

Analog IFs + some Digital functions

Digital functions

Digital + Analog power functions

Analog power functions

Assembly Name	FR FIT MIL 20°C	FR FIT FIDES 20°C	Ratio MIL/FIDES
Board 1	575.4	187.7	*3.07*
Board 2	586.5	80.2	*7.31*
Board 3	289.2	88.1	*3.28*
Board 4	131.7	49.1	*2.68*
SCU	1582.8	405.1	*3.91*

Comparison with in-orbit return (IOR) data (518 cumulated years, no failure):

	FR FIT MIL	FR FIT FIDES	FR In Orbit Return	Ratio MIL/IOR	Ratio FIDES/IOR
On-board Computer (minus reconf – Board 3)	1293.63	317	201.7	6.41	1.57

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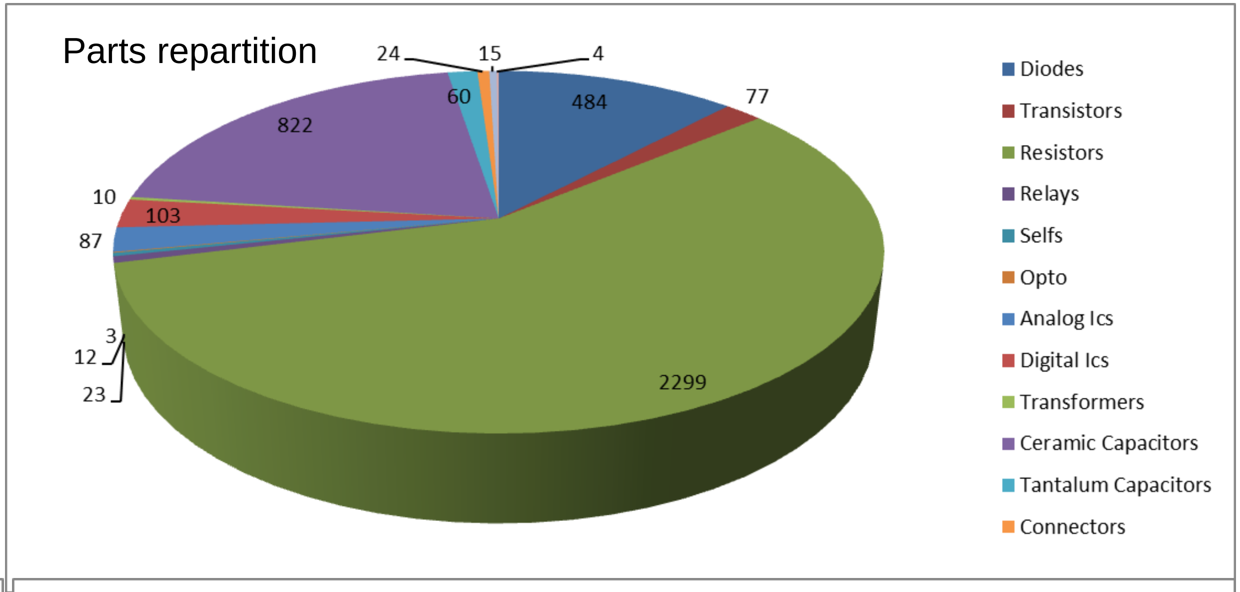
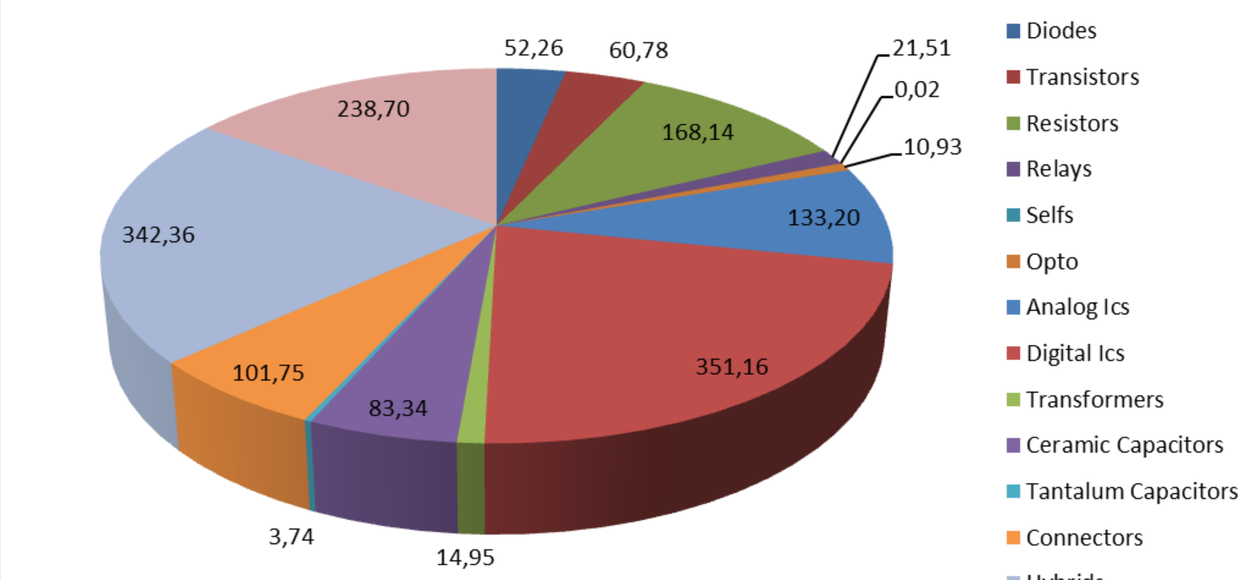
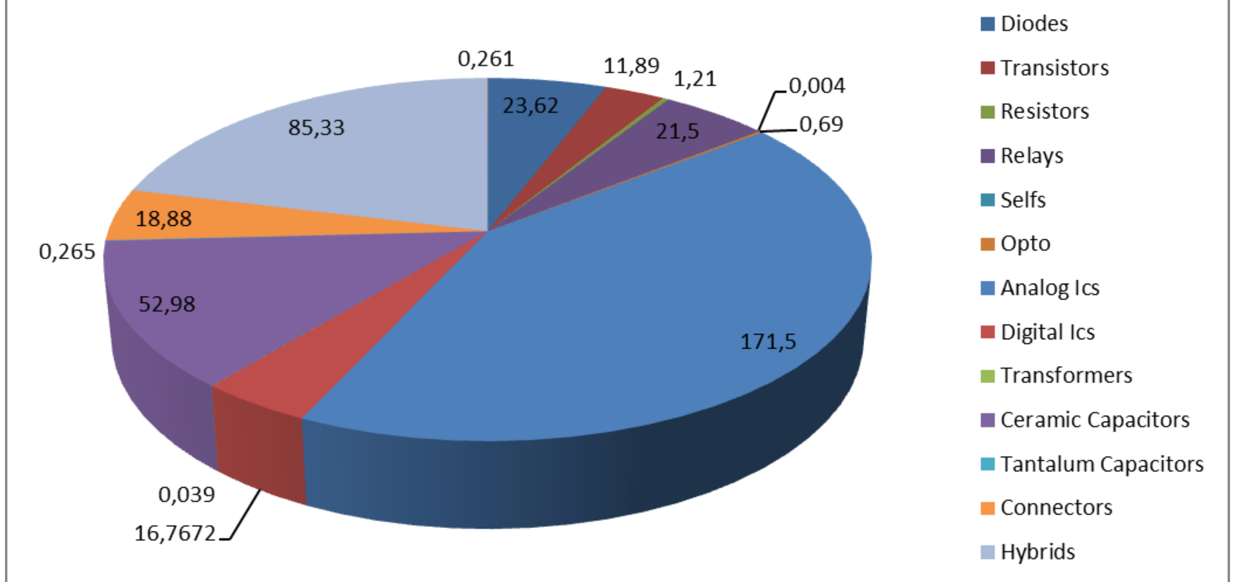
2. The FIDES method – reminder of what it applications

Trends displayed through FIDES more in line with ADS EEE experts‘ observations





Failure Rate repartition with MIL HDBK 217 F N2 (FITs)



Failure Rate repartition with FIDES (FITs)

2. The FIDES method – reminder of what it is and why it is considered for Space applications

- The MIL HDBK, for a long time considered as the main EEE reliability method used in Space becomes obsolete (last update is 1995):
  - ➢ new components not modelled,
  - ➢ new generations of existing components not modelled either,
  - ➢ field return used dates from 1980-1990s.
- MIL HDBK computations do not take into account ON/OFF and thermal cyclings
- Quality levels as modelled through the MIL-HDBK-217 give pessimistic results for commercial parts in particular
- Data calculated through in orbit return (when possible) present much lower reliability values than with MIL, but results are in the same range when calculated with FIDES

Need for realistic predictions…
(e.g. Constellations)

	FR FIT MIL	FR FIT FIDES	FR In Orbit Return	Ratio MIL/IOR	Ratio FIDES/IOR
SCU (minus MRE)	1293.63	317	201.7	**6.41**	**1.57**

2. The FIDES method – reminder of what it is and why it is considered for Space applications

- FIDES makes it possible “to quantify”:

  ✓ Impact of Life Profile on equipment reliability (Ambient Temperature, Thermal cyclings, Vibrations,….):

  ➔ **Life Profile**

  ✓ Reliability impact of a component policy → Quality and level of qualification of the part:

  ➔ **Pi_Part_Manufacturing factor**

  ✓ Impact of the company strategy in term of processes (development, manufacturing, support activities etc…):

  ➔ **Pi_Process factor**

  ✓ Design sensitivity to external factors (overstress, conditions of use, etc…):

  ➔ **Pi_Induced factor**

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3. Evolutions since 2016, current situation and perspectives for FIDES

2001
Beginning of the FIDES project

2004
FIDES 1st issue

2005
FIDES became a UTE standard

2007
Creation of the FIDES working group
-
Beginning of the FIDES 2 project

2009
FIDES 2nd issue

2010
PEA REX validation by military and aeronautics field return

2013
ExperTool free software

2015
Beginning of the PISTIS study

2018
Creation of a working group to make an IEC standard out of FIDES

2020
Scheduled 3rd issue of FIDES

NOW

3. Evolutions since 2016, current situation and perspectives for FIDES

The PISTIS project (2015-2019)

- Collaborative study between 15 companies and academics with the DGA (French MoD)
- Several major updates ongoing to answer the following questions:
  - Reliability of DSM, RF-HF (GaN) and power (IGBT, MOSFET) components
  - FIDES existing models: are they adapted to these new technologies?
  - What about lifetime (wearout) of these technologies?
- With also FIDES models or parameters revision :
  - ➢ Base Lambdas die and case
  - ➢ Pi process Audit
  - ➢ Pi induced (EOS, MOS, TOS)

3. Evolutions since 2016, current situation and perspectives for FIDES

The PISTIS project (2015-2019)

- WP1, 2 and 3: reliability tests

WP1 – DSM :

- ❖ NAND, NOR => tests started in Sept. 2017, 1st failures analyzed
- ❖ FPGA: tests started in Jan. 2018
- ❖ DDR3: tests started in Oct. 2018

WP2 – MOSFET & IGBT :

- ❖ Thermal cycling : started in Oct. 2018
- ❖ Power Cycling, started in July 2018, 1st failures analyzed

WP3 – GaN (+GaAs) :

- ❖ Tests (DC & CW Comp.) on GaN, started in Q1 2017.
- ❖ First results, slight trend to be confirmed.

WP1 – Component families	**Technology node**
FPGA **Xilinx**	28nm
Flash **Micron**	NAND MLC 20nm
Flash Spansion-**Cypress**	NOR 65nm
DDR3 **Micron**	25nm
DDR3 **Micron**	20nm

WP2 - Component families	**Characteristics**
IGBT, **Microsemi**	600V field stop
MOSFET, **Infineon**	N Chan., $V_{(BR)DSS}$ 200V
MOSFET, **STM**	N Chan., $V_{(BR)DSS}$ 650V

WP3 - Component families	**Characteristics**
GaN-HEMT GH25, **UMS**	15W, V_{DS}=30V
GaN-HEMT GL2D, **SEDI**	20W, V_{DS}=43.5V

3. Evolutions since 2016, current situation and perspectives for FIDES

The PISTIS project (2015-2019)

PISTIS

• WP4.1: Screening methods (ESS)

Done :

- ❖ State of the art and Capitalization of screening methodologies, from industrial partners.
- ❖ Guideline about screening methodologies, final validation by DGA

•WP4.2: Aggravated tests (HALT)

Done :

- ❖ State of the art and Capitalization of HALT methodologies, from industrial partners.
- ❖ Guideline about HALT methodology, final validation by DGA

3. Evolutions since 2016, current situation and perspectives for FIDES

FIDES at IEC « A global methodology for reliability data prediction of electronic components »

- 2017 : acceptance of this new proposal by IEC
- 81% success on this vote (results table below)
- Normative standard under IEC-63142 reference on the way
- Standard scheduled for 2022

Approval				
P-Members Voting	P-Members Approving	Approval %	Criteria	Result
16	13	81.3	>= 66.7 %	Approved
Participation				
Number of P-Members	P-Members approving and participating		Criteria	Result
23	7		>=5	Approved

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Scheduled 3rd issue of FIDES

NOW

2009 - ADS: FIDES 2004 audit performed Method applied for Carmat and Military projects

2015 - ADS: First use of the standard for satellites – **OneWeb** project

2015: RPDSM study for ESA
➔ Comparison of FIDES with MIL-HDBK

2017: Beginning of the **NRPM study for ESA** – FIDES used as baseline to model EEE parts

4. Updates on ADS and the European space community wrt FIDES

Airbus Defence and Space and FIDES

- Within Airbus Group, it has been used for years for Civil Aircrafts‘ processors and is currently being used on the Ariane 6 programme.
- Within Airbus Defence & Space, FIDES had been used for years on Defence programmes and specific projects, in agreement with the customer (ex: CARMAT, Artificial Heart)
- Within Airbus Defence & Space, FIDES has been used on Constellations programmes (ex: OneWeb, where it has been applied on almost all electronics units), and is highly recommended for all New Space programmes, to begin with.
- All entities (UK, Germany & France) within the RAMS department in Airbus Defence & Space work together in order to have the same approach for the application of FIDES, approach consistent with the upcoming New Reliability Prediction Methodology to be used in the future.

https://www.reliability.space/

4. Updates on ADS and the European space community wrt FIDES

The European space community and FIDES

- In 2015-2016, the Reliability Prediction Datasources for Space Modelling (RPDSM) study, performed by Airbus Defence & Space for ESA, provided both a quantitative and qualitative analysis of both MIL-HDBK-217F and FIDES for EEE predictive reliability calculations.

  Its conclusion was the recommendation to switch to FIDES for new projects, with foreseen necessary adaptations for the Space applications.

- Since 2017, ongoing study for ESA called New Reliability Prediction Methodology for Space Applications (NRPM) performed with MATRISK as the prime of a consortium with Airbus Defence and Space, Thales Alenia Space, SERMA technologies and SAREL.

  For the EEE components reliability calculations, the main method proposed is FIDES, with some guidance on how to apply it on Space applications.
  Conclusion of the study in 2020.

reliability.SPACE

4. Updates on ADS and the European space community wrt FIDES

IMdR - French Risk Management Institute – FIDES Working Group

Creation in 2017 of a subgroup for Space Applications

Objectives:
- Raise discussions/propositions on how to adapt FIDES to Space applications
- Propose / Define common approaches for the Space community

Topics already broached:
- Mission profiles and Pi Application
- Pi Part Manufacturing – Proposition for updates, validation & simplification
- Pi Process – Discussions on if and how the Audit could be simplified
- Components: Discussions around important contributors (ex: capacitors, RF parts…)

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5. Ongoing actions and way forward

FIDES

- Conclusions of the PISTIS project expected for 2020, jointly with a new release of the guide
- The FIDES method will become an IEC standard in 2022 as well
- The Space subgroup of IMdR will go on addressing the main topics for the application to Space – anybody is welcome to join the discussions
- NRPM study conclusions by the end of 2020
- Within Airbus Defence & Space, the objective is to propose FIDES for all new projects and to discuss /share with both our suppliers and customers to make the switch as easy and organic as possible
- Soon, the OneWeb constellation will be operating and will allow Airbus Defence & Space to compare reliability predictions for EEE units with In Orbit Return for the related mission profile.

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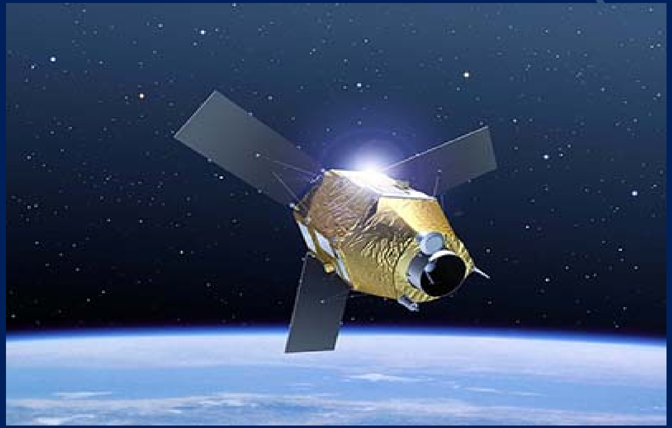

Thank you

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stephanie.bourbouse@airbus.com

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Additional material – FIDES formulae

- The main FIDES formulae are of the form:

$$\lambda = \lambda_{physical} * \pi_{Part\_manufacturing} * \pi_{Process}$$

Physical contribution

Quality and level of qualification of the part

Quality of the process at equipment & system levels

with $$\lambda_{physical} = \lambda_{0\_part} * \Sigma\, \pi_{acceleration} * \pi_{Induced}$$

Impact of thermal cycling, electrical, thermal, chemical, mechanical & humidity influences

Impact of application on the part (placement, application & ruggedizing)

(as a comparison, for MIL HDBK $\lambda = \lambda_{physical} = \lambda_{0\_part} * \pi_{acceleration} * \pi_E * \pi_Q$)

Impact of electro-thermal influence ONLY

Predefined Environment ONLY

Part Quality ONLY

FIDES takes into account more parameters for better granularity.

Additional material – Pi Part Manufacturing

$$\lambda = \lambda_{physical} * \pi_{Part\_manufacturing} * \pi_{Process}$$

Π Part Manufacturing factor

For $QA_{manufacturer}$, which is based on the level of qualification of the manufacturer:

Automotive certification

Manufacturer quality assurance level	Positive relative to state of the art	$QA_{manufacturer}$
Certified ISO/TS16949 V2002	Higher	3
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, **ESCC-QPL**, **MIL-PRF-38535 QML**, MIL-PRF-19500	Equivalent	**2**
ISO 9000 version 2000 certified	Lower	1
No information	Very much lower	0

Lower level of certification

Space & Military certification

Additional material – Pi Part Manufacturing

$$\lambda = \lambda_{physical} * \pi_{Part\_manufacturing} * \pi_{Process}$$

Π Part Manufacturing factor

For $QA_{component}$, based on the standards used for the qualification of the component (example of the ICs):

Component quality assurance level	Position relative to the state of the art	$QA_{component}$
Qualification according to one of the following standards: **AEC Q100**, **MIL-PRF-38535 class V**, **ESA ESCC 90xx,** NASDA-QTS-xxxx class I, NPSL NASA level 1	Higher	3
Manufacturer qualification including tests conforming with standards JESD22, EIAJ-ED-4701, MIL-STD-883, IEC 68 with identification of "front-end" and "back-end"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, NASDA-QTS-xxxx class II, NPSL NASAlevel 2 & 3 , STACK-S0001	Equivalent	2
Qualification program internal to the manufacturer and unidentified manufacturing sites	Lower	1
No information	Much lower	0

Automotive level

ESCC class 1 (QML-V)

ESCC class 2/3 (QML-Q or M)

AIRBUS

Additional material – Pi Part Manufacturing

$$\lambda = \lambda_{physical} * \pi_{Part\_manufacturing} * \pi_{Process}$$

- The other factors are :

  - ε, representing the level of confidence in the manufacturer for a given part
  This factor is defined in Airbus DS based on audit reports from the EEE team

  - $Ra_{component}$, representing the tests for the active parts
  This factor has to be adapted for space applications – propositions provided for NRPM