Reliability Applied to KM3NET

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CLB meeting 30/01/2014

Who am i?

- Stéphane COLONGES
- APC Laboratory
- Electronic Product Assurance Manager
- Activities:
  - Support engineering to improve reliability
  - Components & system qualification
- Projects:
  - Auger Observatory (1830 boards in harsh environment)
  - Space projects: Taranis, SimbolX, R&D anti-coïndidence
  - CTA observatory (QAM)

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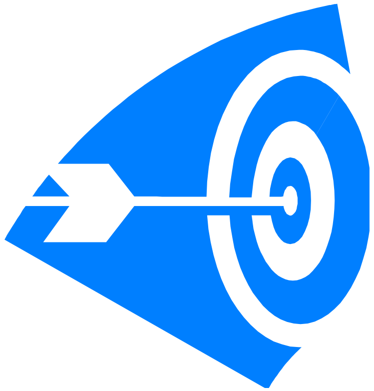
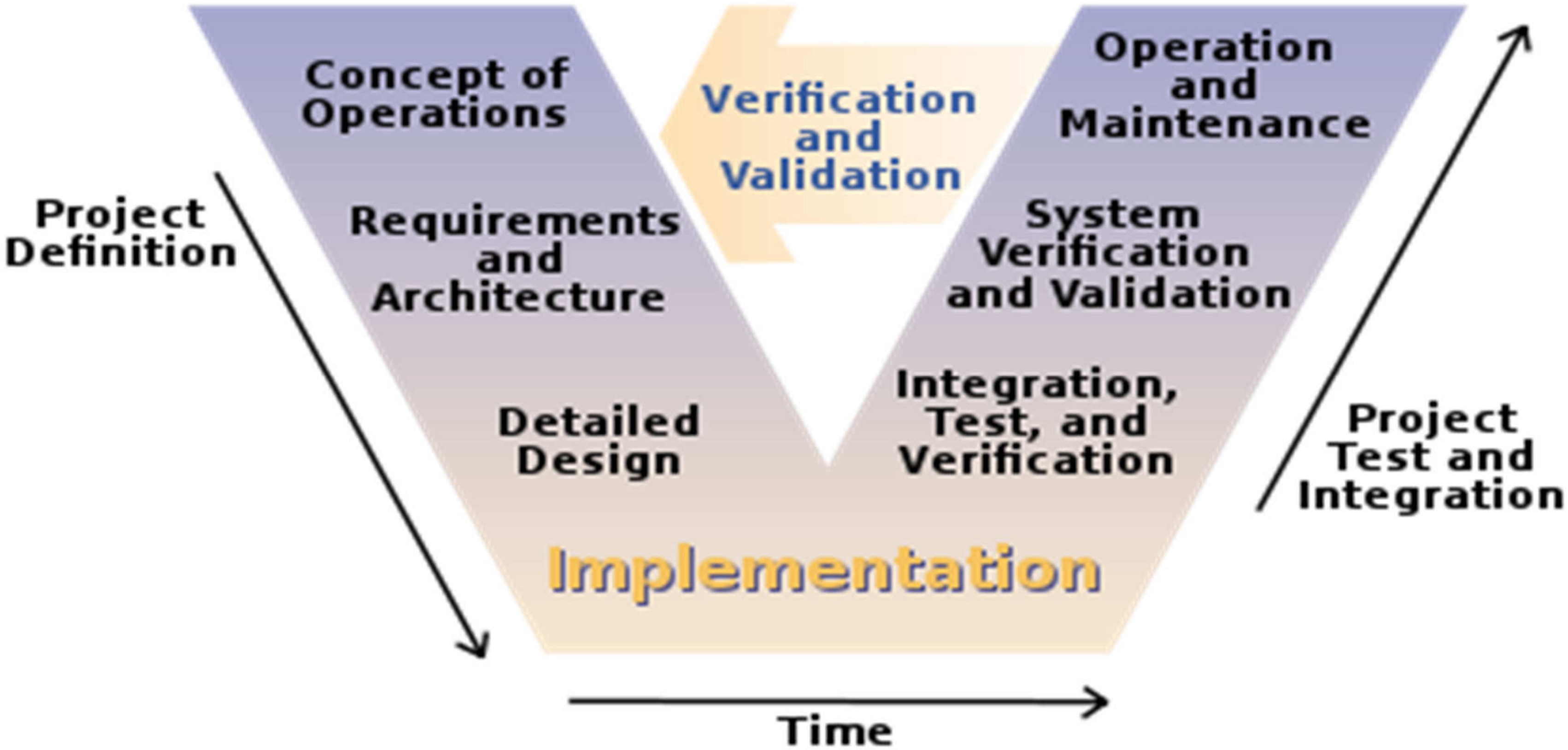


Development process

V Cycle



Concept of operation

- Product definition (scientific needs)

  Think Needs before solutions!

- Constraints (environment, life cycle, maintenance, costs…)

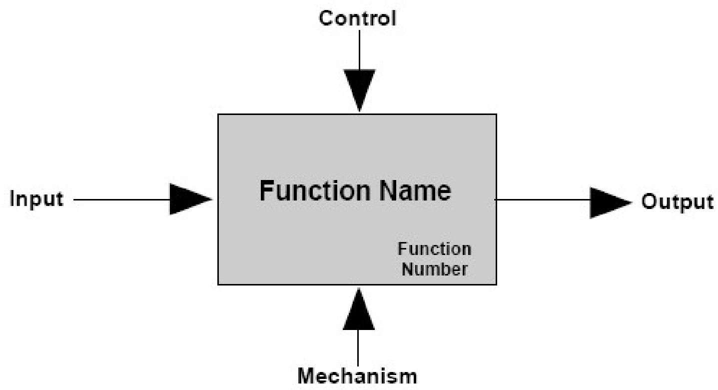
Requirements and architecture

-Requirements (functional, performances, environmental, RAMS…)

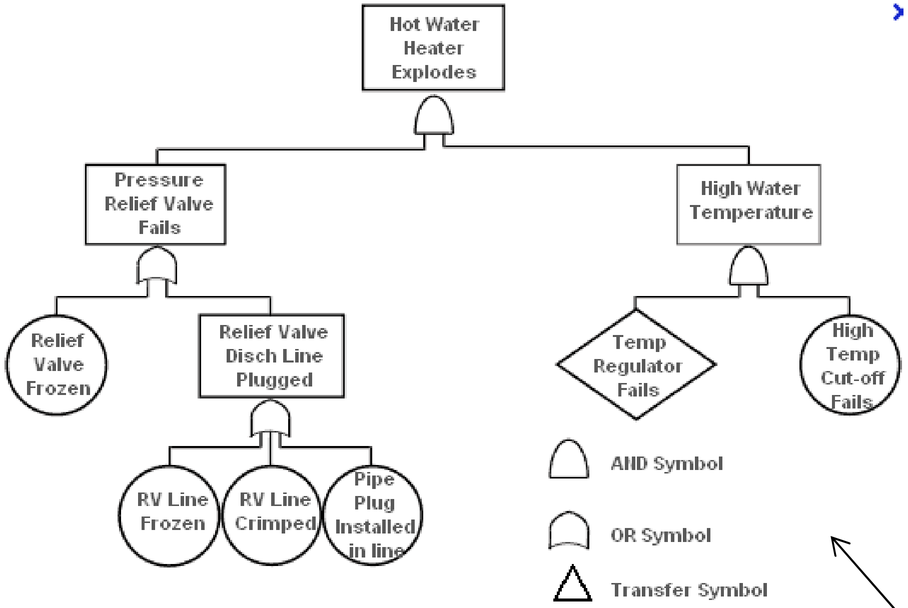
-Functional analysis (SADT method)

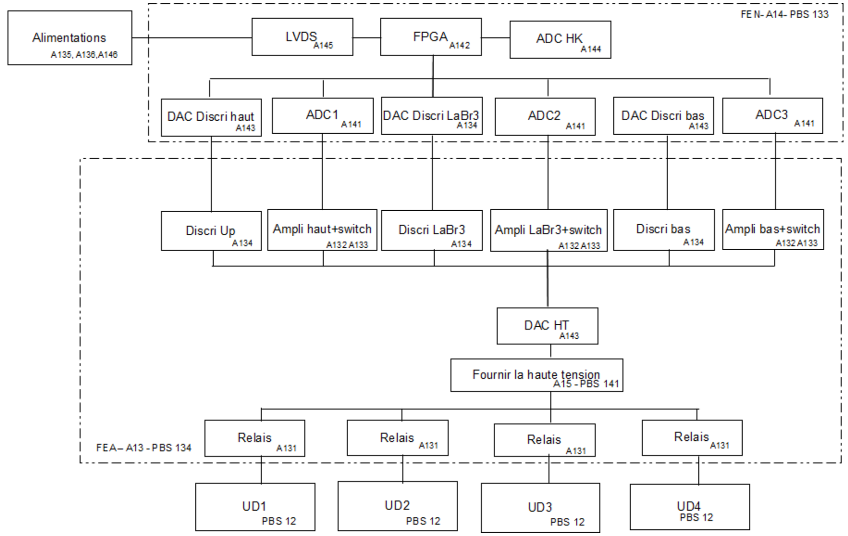
-Applicable needs

-PBS



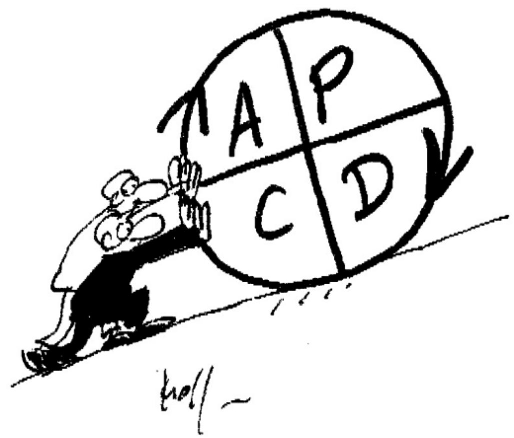
Requirements and architecture





-FMECA (using tools like FTA and RBD) ➔ Avoid SPF, reduce failures criticism

➔ Iterative process!



FMECA

Project: Version: Date:

System: Subsystem: Teamwork leader:

Id.	Comp.	Function	Failure mode	Failure cause	Local effects	Global effects	S	O	D	RPN	Corrective actions

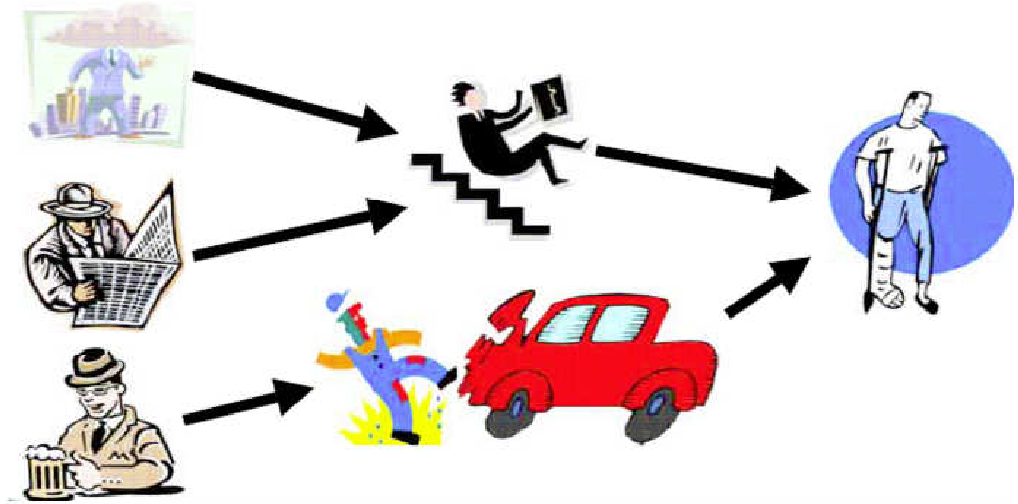
Design

Good conception = high reliability

Parts selection, consider:

- Obsolescence (Vs LTA) , maturity, wide distribution
- Environment: temperature, ESD, salt, humidity…
- MTBF (FIT)
- ROHS Vs Whiskers?
- Improve reliability (Derating - ECSS-Q-ST-30-11C, redundancies, ESD protections, ESR compromise…)

Design



Reliability analysis

- MTTF :

- Acceptable failure rate?
- Spare quantities

- FMECA (identify failure modes and reduce effects).

Iterative process:

– Identify the weakness points
– Identify failure type and process
– Change the design to improve reliability

Design

Critical Design Review:

- Objectives:

-Validate the detailed product conception

-Prototype analysis and test results

-Check the product conformity with the specifications

- Documentation:

-Definition justification document

-Manufacturing files, procedures and documents

-RAMS plan and FMECA (Reliability analysis) & MTBF evaluation

-Interfaces Control Document

-Preliminary user guide

Pre-production (Detailled design)

-Goal:

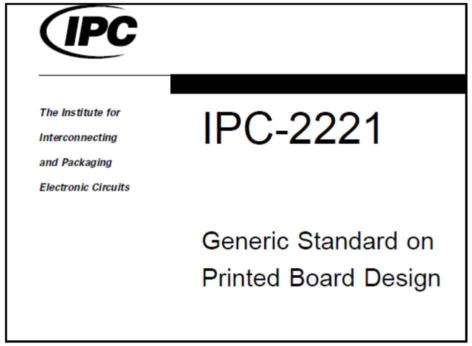
-Produce a small quantity of boards, update the design to production process, design hardening

-Industrialization:

-PCB rules (IPC2221… IPC600…)

-IPC class 2

-Manufacturing and soldering processes


IPC

The Institute for Interconnecting and Packaging Electronic Circuits

IPC-2221

Generic Standard on Printed Board Design

-Manufacturing test and inspection (In situ tests, test bench…)

-HASS procedure (eliminate youth failures)

-Environment protection (coating, ESD suppressor…)

-Storage, packaging, handling…

Pre-production (Detailled design)

-Production Readiness Review:

-Manufacturing sub-contractor, public tender…(instructions, CCTP…)

-Industrial files

Production (Implementation)

-Dividing in batches, allow to:

-Detect weakness point (PCB layout, production process)

-Change layout or production process (non conformities correction)

- Configuration follow up :

-Non conformities taken into account

-Modification taken into account

-Document folder: customer/sub contractor use the same files and document version

Document folder example

RÉPERTOIRE DOCUMENT

DÉSIGNATION : Carte AUGER - IN2P3 ("carte unifiée")
INDICE : K

Date de mise a jour : 08/10/03

réf. du sous document	Indice	Désignation du sous document	Nombre de folios / remarques
NomAuger04072003 (document Excel)	G	Nomenclature carte unifiée AUGER	Nomenclature des composants
Bill of matériel (document .txt)	A	Version 1.3 ==> repères topologiques	Intégrée et mise a jour dans la nomenclature de la carte unifiée AUGER (version obsolète)
Fabrication_Instructions (document Word)	E	Instructions de fabrication de la carte unifiée	Instructions générales de fabrication : en particulier, instructions de câblage, instructions de tropicalisation, instructions d'emballage ...
Instructions de programmation (document Word)	D	Instructions de programmation	Instructions logiciel
specificationgenerales (document Word)	B	Spécifications générales : compte rendu de la réunion du 24/10/2002	Spécifications générales (réunion du 24/10/2002)
testfonctionnelub (document Word)	C	Procédure de test fonctionnel	Description du test fonctionnel
deverminagespecifications (document Word)	E	Procédure de deverminage	Description de la procédure
Schéma électronique	C	Relatif aux fichiers de fabrication Unified Board version 1.4 schemaUB1V4.tgz	Cette version inclue les plages de test
PLD.pdf	A	Schema interne du PLD	
Fichiers gerbers : Gerber21.tgz Incluent en particulier : plan de routage plan de sérigraphie Masque de vernis épargne Masque de refusion (PASTEMASK_TOP2.1.art) plan de perçage	F	Fichiers gerbers du CI version 2.1 (Gerber étendu RS274-X) TOP.art modifié entre indice D et E SERI_TOP.art modifié entre indice D et E VE_TOP.art modifié entre indice D et E (Masque de refusion modifié entre versions D et E. M44 enlevé car non soudé) Non modifié entre version D et E	Fichiers Gerbers 4 couches : routage Top et Bottom et plan internes Sérigraphie top et bottom Verni épargne top et bottom Masque de refusion pour la soudure des composants CMS
plan d'implantation TOP et BOTTOM	A	Fichiers acrobat reader (topUB1V4.pdf, botUB1V4.pdf)	
SpecificationsCI	B	Spécifications pour la réalisation du circuit imprimé	Spécifications particulières pour le circuit imprimé
extract20.val.gz	B	Fichier Fabmaster pour UB version 2.0	Fichier Fabmaster (pour test in-situ) relatif aux fichiers gerbers version 2.0 pour la fabrication de la carte
			[illegible]

Production (Implementation)

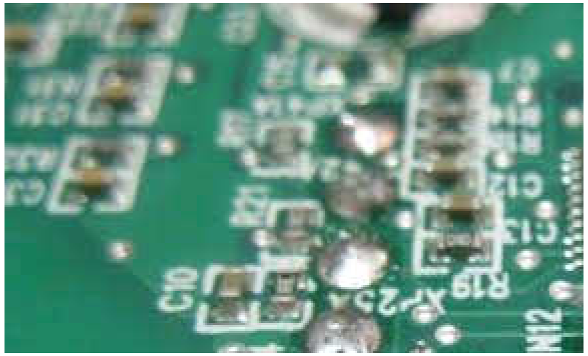
Define a common test and HASS strategy:

-Visual inspection

-Boundary Scan, In situ test (nails), mobil probe

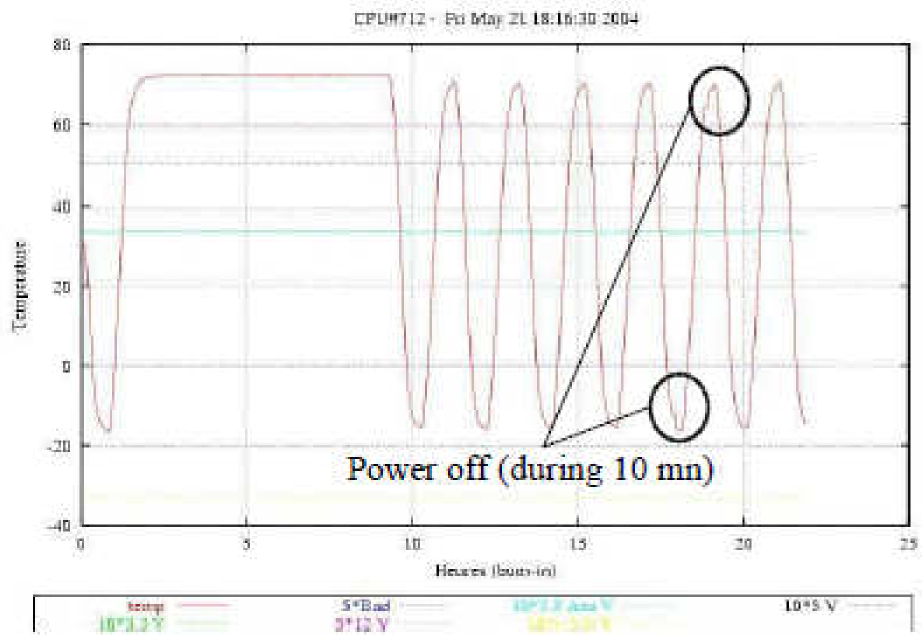
-HASS or ESS with light functionnal test

-Functionnal test ➔ perform in the manufactory



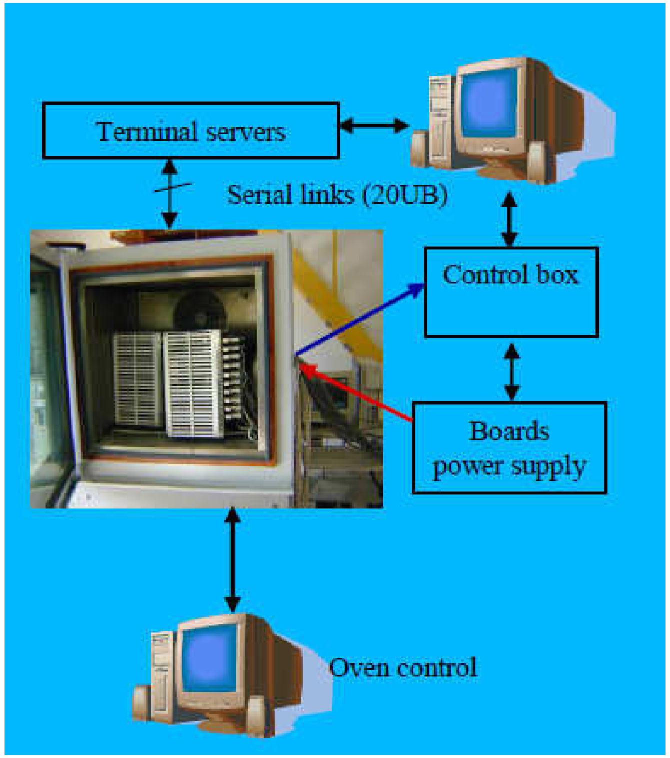
Production (Implementation)

Burn-in and stress screening



Picture 5 : temperature cycles applied on UB

(from -20 to 67°C – 3°C/mn slope - burn-in 8 hours – 7 temperature cycling – 30 mn dwell time - Total duration 23 hours - 20 UB in the oven)



Production (Implementation)

Auditing:

-Relation customer/supplier ➔ as flexible as possible

-Win-Win relationship ➔ they have interest in science project (pub). We want the higher quality product

Production (Implementation)

The FIDES methodology (from page 259) identifies a list of recommendations which, if followed, will facilitate construction of a product reliability. This set of recommendations has been broken down into a set of questions.

The answers that a company gives to these questions provides:

- a measurement of its ability to make reliable products,
- a quantification of the process factors used in the calculation models,
- the possibility of identifying improvement actions.

Production (Implementation)

Audit procedure

To control an audit, the auditor must:

- Identify the audit scope.
- Prepare the audit.
- Perform the audit.
- Collect proofs.
- Process the collected information.
- Draw conclusions.
- Write an audit report.
- Present the audit result.

Production (Implementation)

Level	Process	$\Pi_{Process}$	Process grade
Very high reliability	Process almost with no weakness	<1.7	> 75%
High reliability	Controlled process, reliability engineering	1.7 to 2.8	50% to 75%
Standard	Usual ISO 9001 version 2000 type quality procedures	2.8 to 4.8	25% to 50%
Unreliable	Reliability problems not taken into account	>4.8	<25%

Evaluate (audit) process influence with: FIDES Mill V2004A - Process.xls

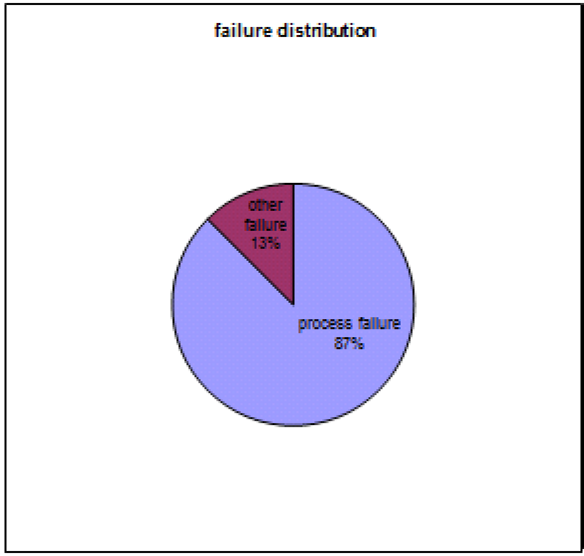
- And fill Π Process : Π_P = 4,00

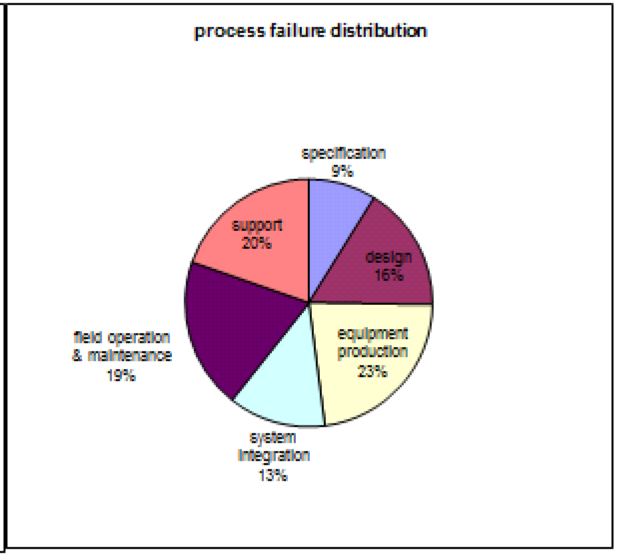
in result1_stress of FIDES Mill V2004A -2- Component.xls

Production (Implementation)

FIDES Mill V2004A - Process.xls

	Contributio n (of marks ot the	Mark obtained	By max mark	Contributio n (of the theoretic	Process grade			Percentage of failures of each phase
specification	#DIV/0!	0,0	433,9	8,0%	0%	$\Pi_{Specification}$ =	1,18	7,7%
design	#DIV/0!	0,0	867,7	16,0%	0%	Π_{Design} =	1,39	14,3%
equipment production	#DIV/0!	0,0	1 301,6	24,0%	0%	$\Pi_{Production}$ =	1,65	19,9%
system integration	#DIV/0!	0,0	650,8	12,0%	0%	$\Pi_{Integration}$ =	1,28	11,2%
field operation & maintenance	#DIV/0!	0,0	1 084,7	20,0%	0%	$\Pi_{Field\ operation}$ =	1,52	17,2%
support	#DIV/0!	0,0	1 084,7	20,0%	0%	$\Pi_{Support}$ =	1,52	17,2%
Total process ==>		0,0	#######		0%	$\Pi_{Process}$ =	8,00	87,5%





For each phase help to define the influence of the process in term of reliability (Questions and recommandations…)

Audit example use Fides excel tool

	Audit question	Recommendation	Description	Recom Weighting		Description	NA	Application level L1	L2	L3	L4	Raw Points	Weighted Points
6	Is a final test of the equipment performed? Do test result non-conformities give rise to processing: at the level of the equipment; at the level of the process?Are the test results recorded?	Improve the equipment final test seen in Design and Specification to increase the test coverage and draw up a test assessment	The final test of the equipment and more particularly the level of coverage achieved by that test must be studied and defined with respect to the equipment's Specification and Design. This test must check the equipment according to the procedures of a System Testability Manual while: Orienting towards a processing in the case of a nonconformity, Recording the results in the manual to ensure test follow-up.	6	L1	L1 : No revision of the predefined test coverage rate is carried out.	-	0	-	-	-	0,0	0,0
18	Is there monitoring of the inspection parameters during the varnishing activity?	Ensure monitoring of the inspection parameters during the varnishing activity	The subassembly varnishing activity, which must lead to an immunity with respect to a certain number of stresses that could reduce the reliability of the subassembly, must be carried out with a permanent inspection relative, in particular, to the monitoring of the main parameters, that is to say: The humidity rate, The temperature, The quality of the varnish's components, The varnish's deposit thickness, Furthermore the viscosity of the varnish must be checked at least once daily.	9,9	L1	L1 : None of the inspection parameters are monitored during the varnishing activity.	-	0	-	-	-	0,0	0,0
			The maintenance procedures										

Installation (Integration, test and verification)

-Installation procedures:

-10% of failures = human error

-ESD and lightning protection

-Test bench (laboratory)

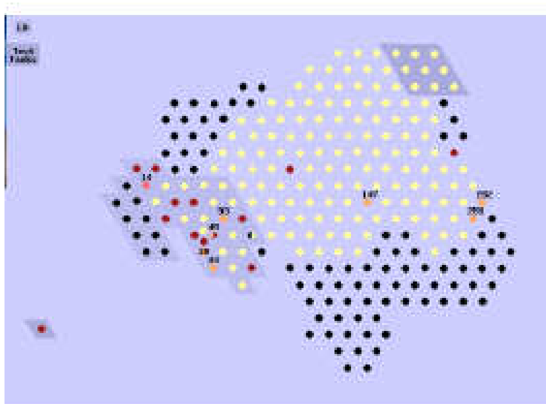
-Test facilities (to test systems on the site before installing lines)

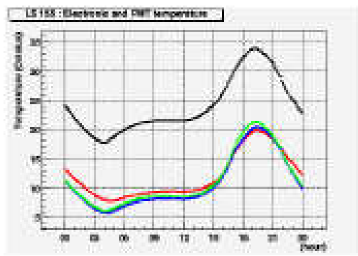
Commissionning (System verification and validation)

-Verify functions and performance according to requirements

-Parameters useful for failure detection correctly monitored

-Monitoring software (easy abroad parameters access)





Operation and maintenance

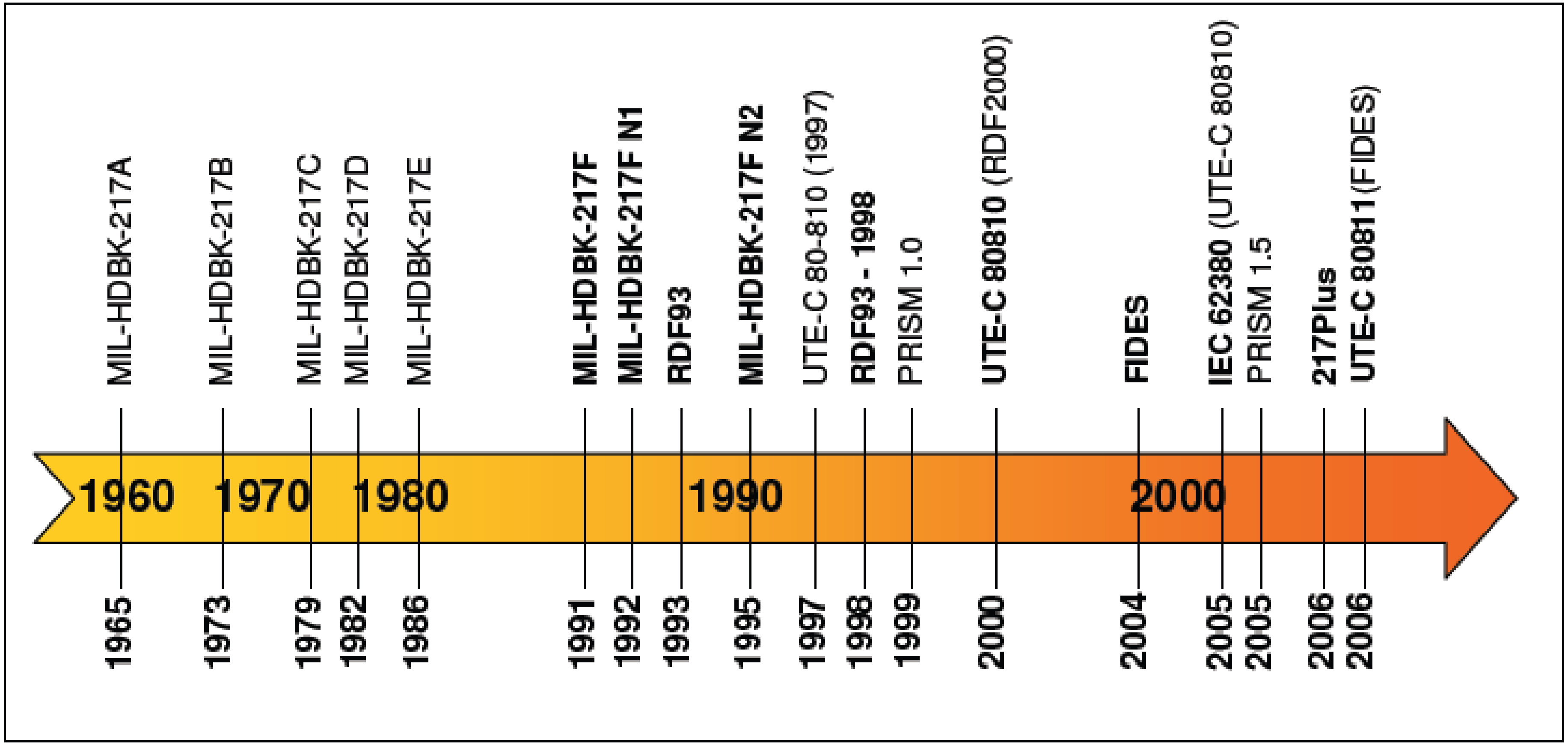
- Evaluate maintenance resources (spares quantities, costs, people…)
- Recovery procedures
- Update FMECA and MTTF: iterative update using experiment feedback (failures data collection)
- Database
- Record maintaining activities
- Local staff training

Reliability for KM3net

How to jump on the bandwagon?

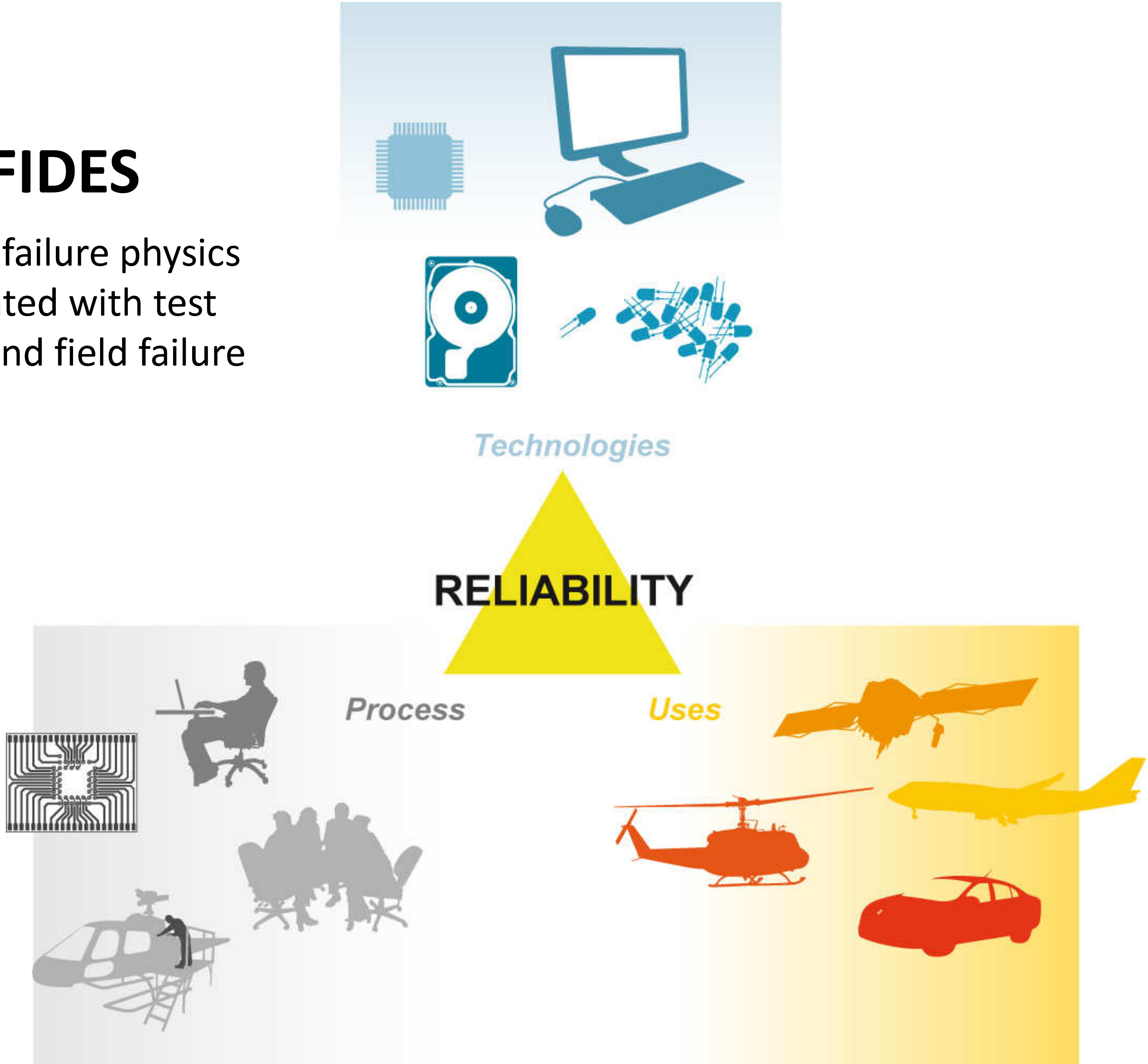
1) Requirements and functional analysis
2) MTTF analysis and FMECA
3) Verify design rules (Derating…)
4) Documentation
5) Review
6) Then next steps (pre-prod, Production, …)

Reliability analysis - Tools



FIDES

- Based on failure physics and calibrated with test feedback and field failure data



FIDES Begins

Why FIDES ?

- Reliability Data book prediction are obsolete! (don't cover actual component technologies)
  - ➔ MIL-HDBK-217 is not maintained since 1995
- FIDES ➔ Funding in 2001 by DGA (French DoD) and 8 international companies (+ BOEING, JAXA, CNES, CNRS… interested)

Handbook and tools :

www.fides-reliability.org

MBDA MISSILE SYSTEMS

nexter ELECTRONICS

THALES
THALES RESEARCH & TECHNOLOGY

THALES

THALES
THALES UNDERWATER SYSTEMS

THALES
THALES AIRBORNE SYSTEMS

eurocopter an EADS Company

FIDES

Based on physics failure , accelerating factors and process contribution:

$$\lambda = \left(\sum_{Physical\_contributions}\right) \times \left(\prod_{Process\_contributions}\right)$$

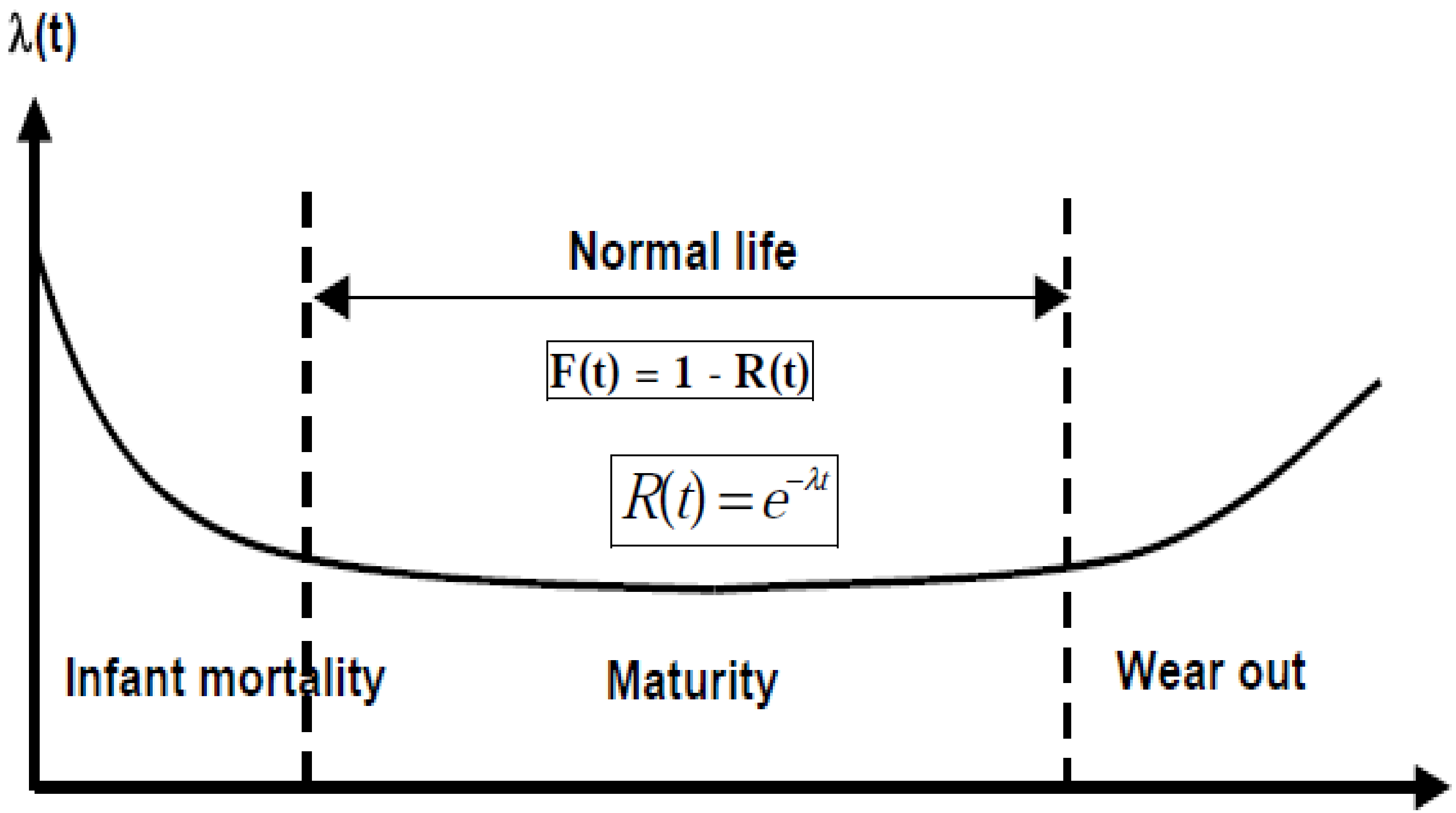
$$\lambda_{Physical} = \left[\sum_{Physical\_Contributions} \left(\lambda_0 \cdot \Pi_{acceleration}\right) \right] \cdot \Pi_{induced}$$

$$\Pi_{PM} = e^{\delta_1 \cdot (1 - Part\_Grade) - \alpha_1}$$

$$Part\_Grade = \left[\frac{\left(QM_{manufacturer} + QA_{item} + RA_{component}\right) \times \varepsilon}{36} \right]$$

Stress	Physic of fialure law	Stress symbol	s = stress number	g Function	Acceleration factor
Thermal	Arrhenius	T	1	$g1 = \frac{1}{T}$	$\exp\left[\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right]$
Thermal cycling	Norris-Lanzberg	T & ΔT	2	$g1 = \frac{1}{T}$ $\mathbf{g2} = \ln(\Delta T)$	$\left(\frac{\Delta T2}{\Delta T1}\right)^m \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T\,\mathbf{max\_}ref} - \frac{1}{T\,\mathbf{max}}\right)\right)$
Humidity	Haldberg-Peck	RH	2	$g1 = \ln(RH)$ $\mathbf{g2} = \frac{1}{\mathbf{T}}$	$\left(\frac{RH2}{RH1}\right)^p \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right)$
Vibration	Basquin	Grms	1	$g1 = \ln(Grms)$	$\left(\frac{Grms\ \ 2}{Grms\ \ 1}\right)^b$
Electrical	Eyring	T & V	2	$g1 = \ln(V)$ $\mathbf{g2} = \frac{1}{\mathbf{T}}$	$\left(\frac{V2}{V1}\right)^n \cdot \exp\left(\frac{Ea}{Kb} \cdot \left(\frac{1}{T1} - \frac{1}{T2}\right)\right)$

MTTF / Bath tub

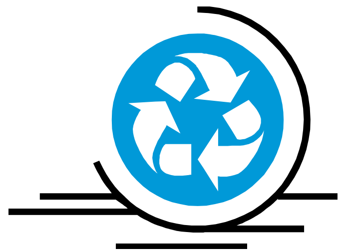


Conclusion

- People should be aware on QA added value!
- Your collaboration is necessary
- Keep in mind: reliability is an iterative process

…

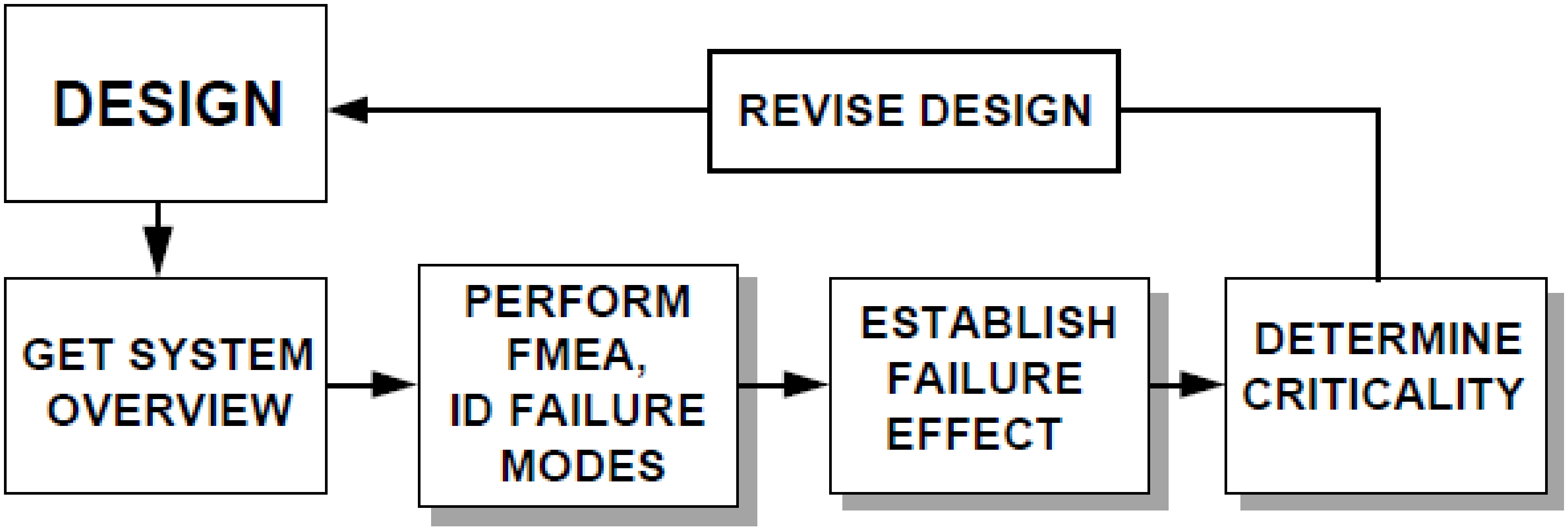
And 2 other words : Brainstorming and workgroups…



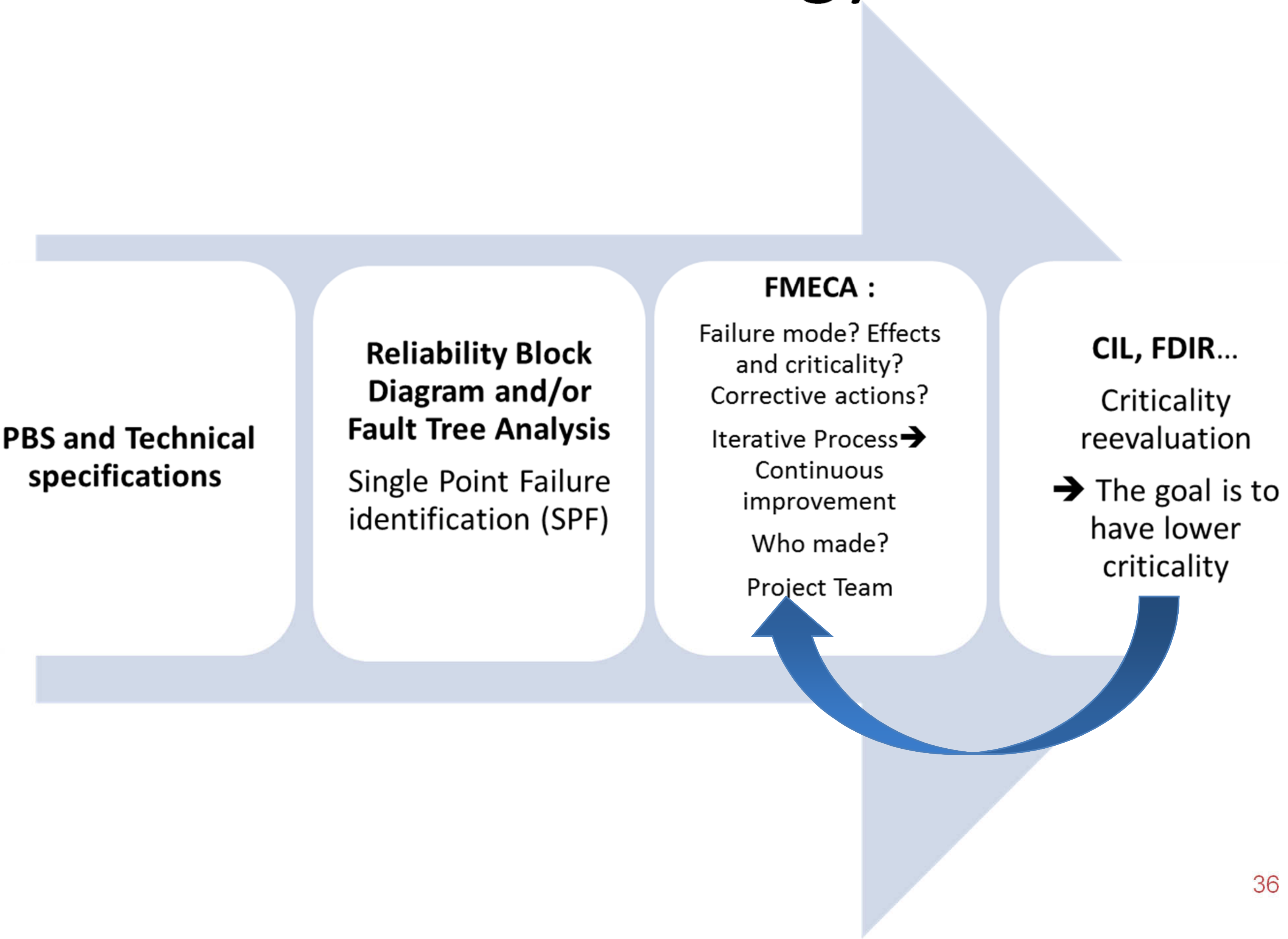
More slides…

FMECA An iterative process

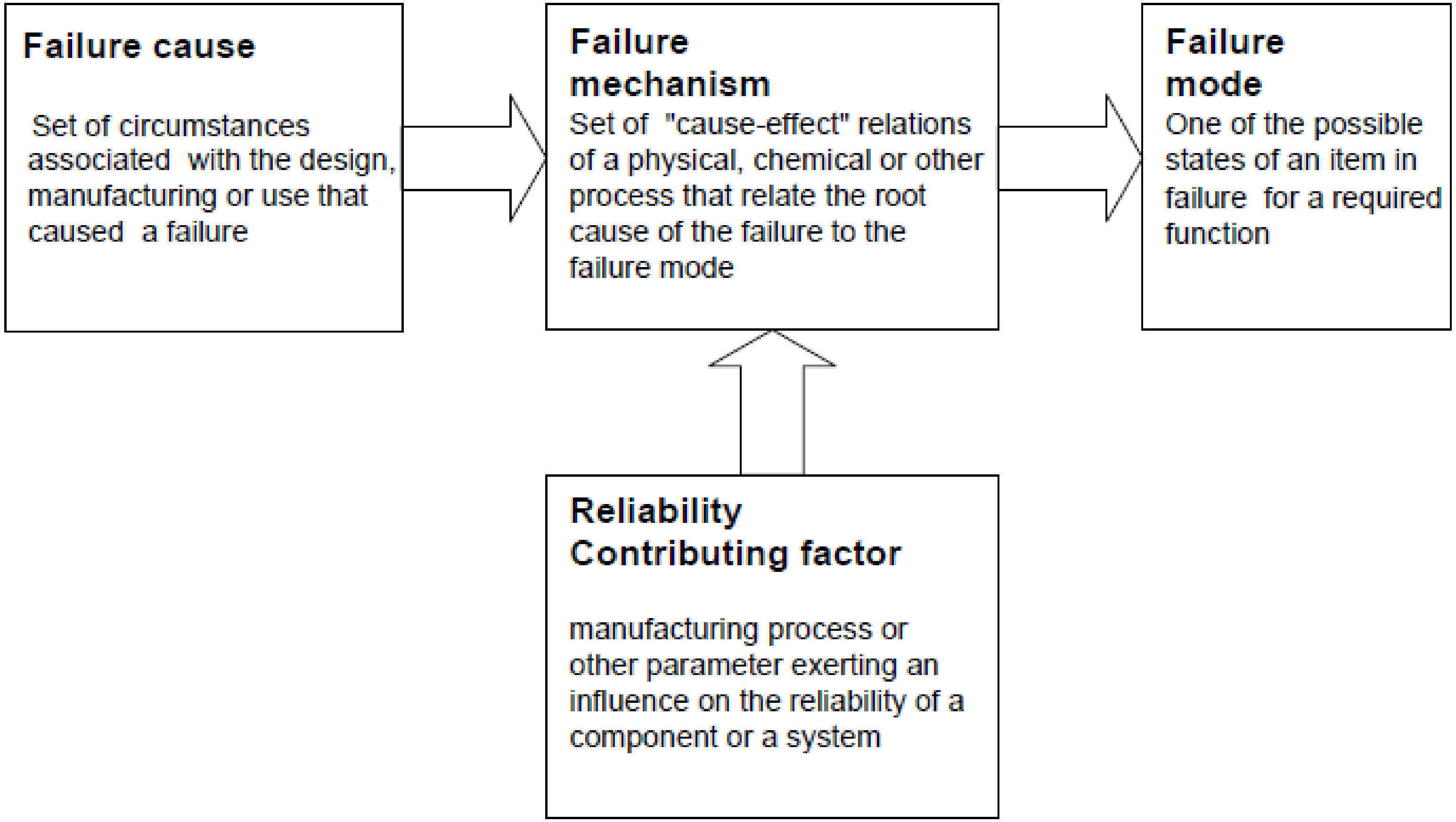
PROCEDURE-FLOWCHART



Methodology



Reliability analysis - Methodology



MTTF / Temperature

- Composants optiques : 0.8 eV
- Bipolar Ics, transistors, diodes : 0.7 eV
- MOS ICs : 0.6 eV
- T1: normal temperature (related to the FIT)
- T2: new temperature

$$\lambda(T_2) = \lambda(T_1) \times \exp\left[\frac{E_A}{K} \times \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

Avec la constante de Boltzman : K= 8.63 * 10^{-5}eV/K

FMECA

Identification number	Function	Failure modes and causes	Failure effects			Failure detection method	Compensating provisions	Severity class	Remarks
			Local effects	Next higher level	End effects				
1 (no component id. available)	External power supply	Low voltage			System shut down	IGONACUT signal is active	Shut down system and charge batteries, check solar panel and solar panel controller	IV	
2	Power protection and control	No shut down when occurs a low voltage on the input, or constant shut down		Voltage too low, or no voltage	Power supply problems or no supply (fuse may fuse)	Current consumption is higher if low voltage, or no power	Check components describes for this function in table 1, and repair what is necessary to	III or IV	
21	Comparator	Bad information on the output	No detection of voltage problem	Bad trigger for the timer	See line 2	No trigger or constant trigger on the input of 22	Check M21, change if necessary	III or IV	
22	Timers	No change on the output after a trigger; Timing problem			See line 2	No shut down when low voltage occur, or repetitive shut down	Check component described in table 1	III or IV	