NEW PRODUCT INTRODUCTION METHODOLOGY FOR RELIABLE SMART PRODUCTS

GEERT WILLEMS – IMEC

CENTER FOR ELECTRONICS DESIGN & MANUFACTURING

EDM
Electronics Design & Manufacturing

Met steun van:

AGENTSCHAP INNOVEREN & ONDERNEMEN

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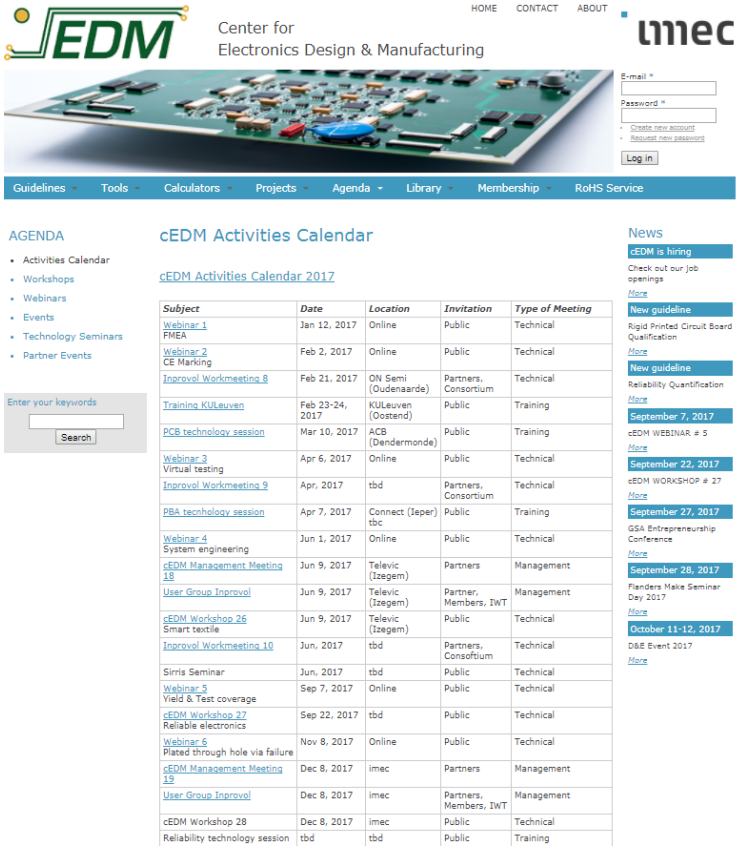

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New Product Introduction for the Smart World

The Reliability Challenge

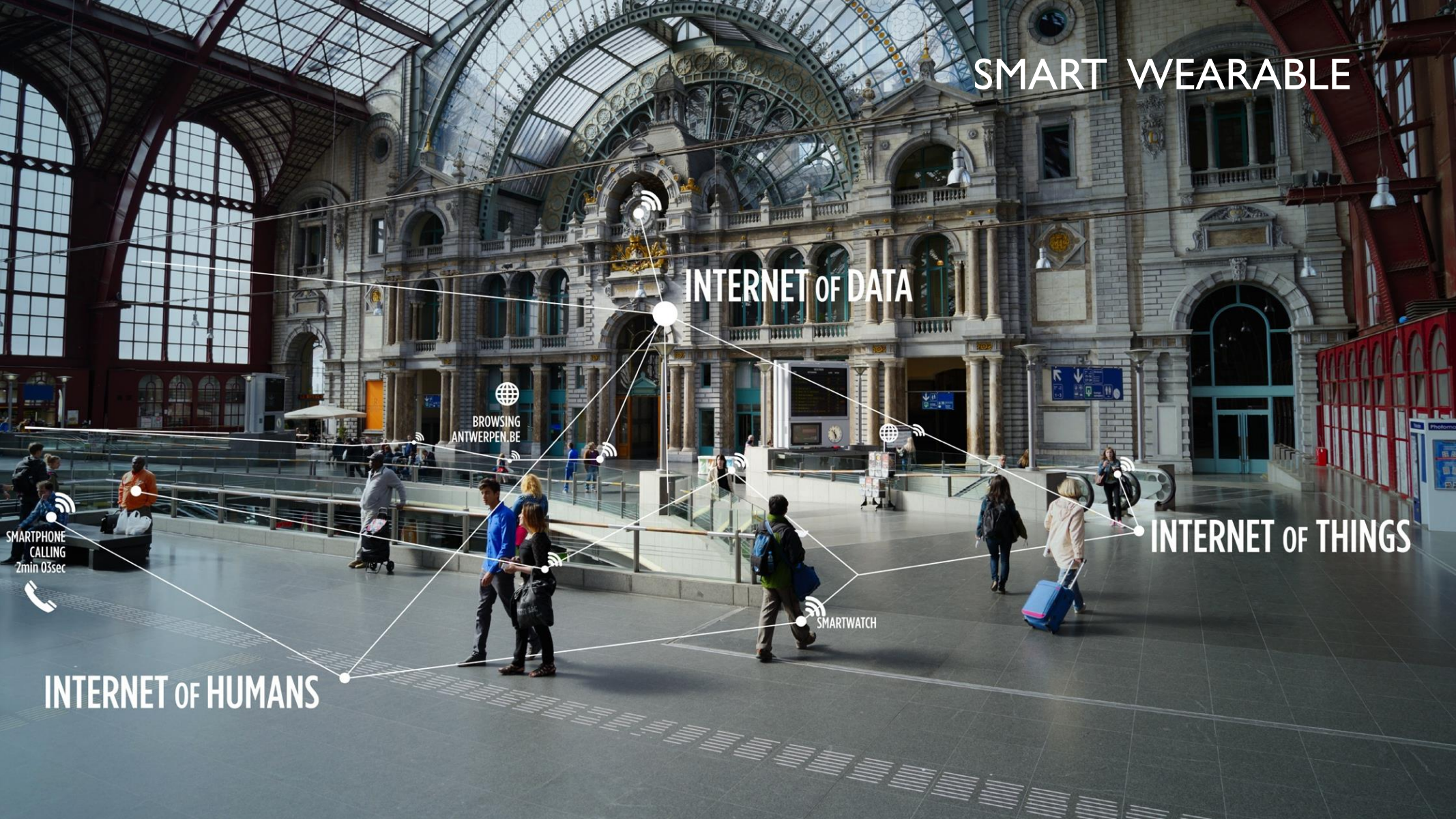
A Smart NPI (reliability) example

THE SMART WORLD

Article
June 2015

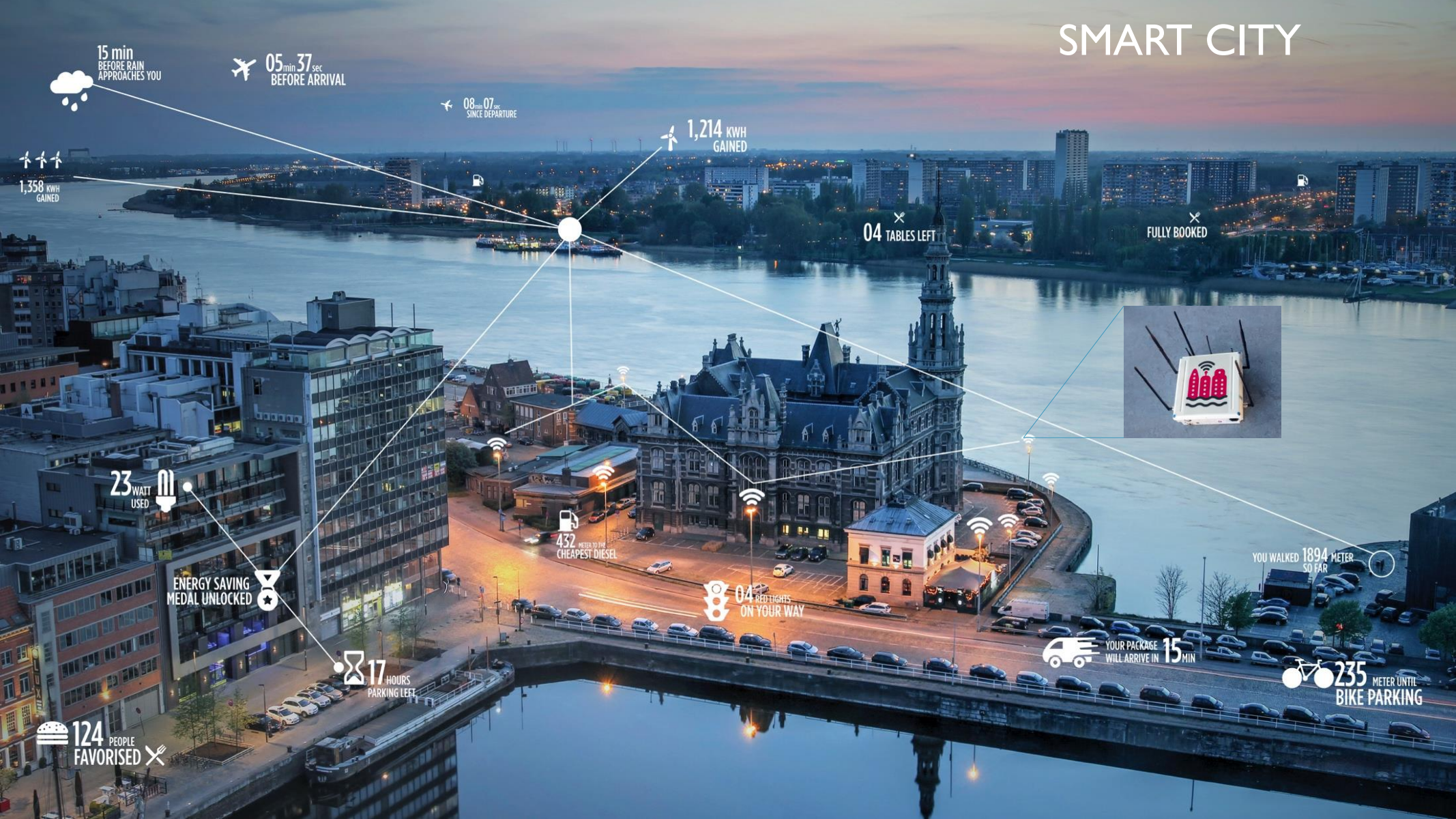
Manufacturing's next act

By Cornelius Baur and Dominik Wee


SMART WEARABLE
INTERNET OF DATA
BROWSING
ANTWERPEN.BE
SMARTPHONE
CALLING
2min 03sec
INTERNET OF THINGS
SMARTWATCH
INTERNET OF HUMANS


SMART CAR
Knowledge base
&
Deep learning
in the Cloud
Real-time execution

SMART CITY


15 min
BEFORE RAIN
APPROACHES YOU
05 min 37 sec
BEFORE ARRIVAL
08 min 07 sec
SINCE DEPARTURE
1,214 KWH
GAINED
1,358 KWH
GAINED
04 TABLES LEFT
FULLY BOOKED
23 WATT
USED
ENERGY SAVING
MEDAL UNLOCKED
432 METER TO THE
CHEAPEST DIESEL
04 RED LIGHTS
ON YOUR WAY
YOU WALKED 1894 METER
SO FAR
YOUR PACKAGE
WILL ARRIVE IN 15 MIN
17 HOURS
PARKING LEFT
235 METER UNTIL
BIKE PARKING
124 PEOPLE
FAVORISED

THE "SMART WORLD"

WHAT IS NEW ABOUT "SMART WORLD"?

- Closing the loop between control and operation:
  (real time) feedback
- Exploitation of an increasing amount of information
- (Self-)Learning, dynamic, adaptable systems

Why now?

It has become affordable: low-cost, high-performance electronics.

THE "SMART WORLD"

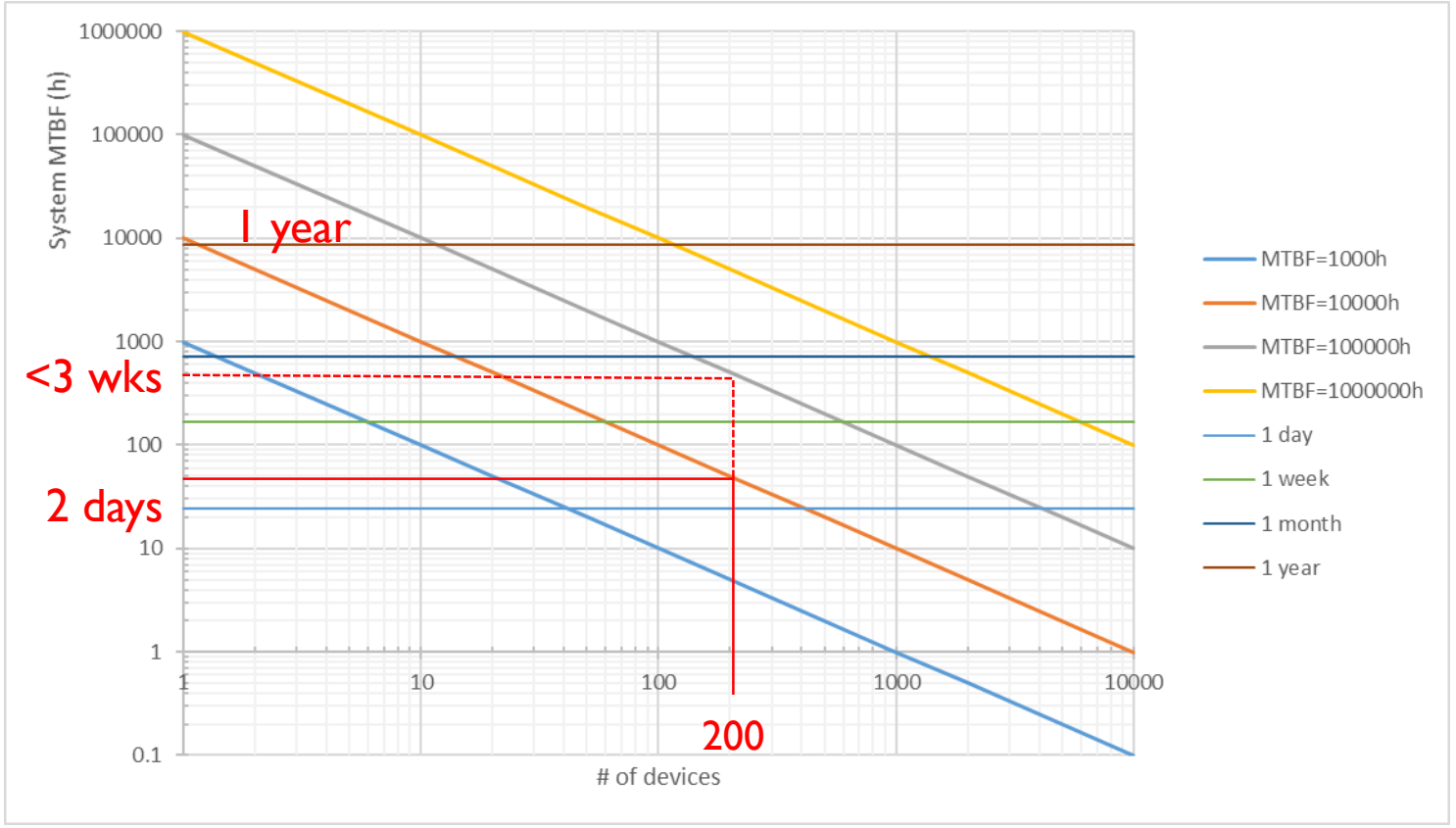
"SMART WORLD" SYSTEM CHARACTERISTICS

- **Software** (AI) using
- a high number of (wireless) **interconnected & distributed** innovative **electronic hardware** modules (sensing, computing, communication, power)
- New devices in different often hard-to-reach and/or harsh environments
- May be safety critical
- High severity at failure
- Dynamic: growing number of variable applications

THE "SMART WORLD"

QUALITY AND RELIABILITY: TIME BETWEEN FAILURE

In the Connected World Reliability is Essential



THE "SMART WORLD"

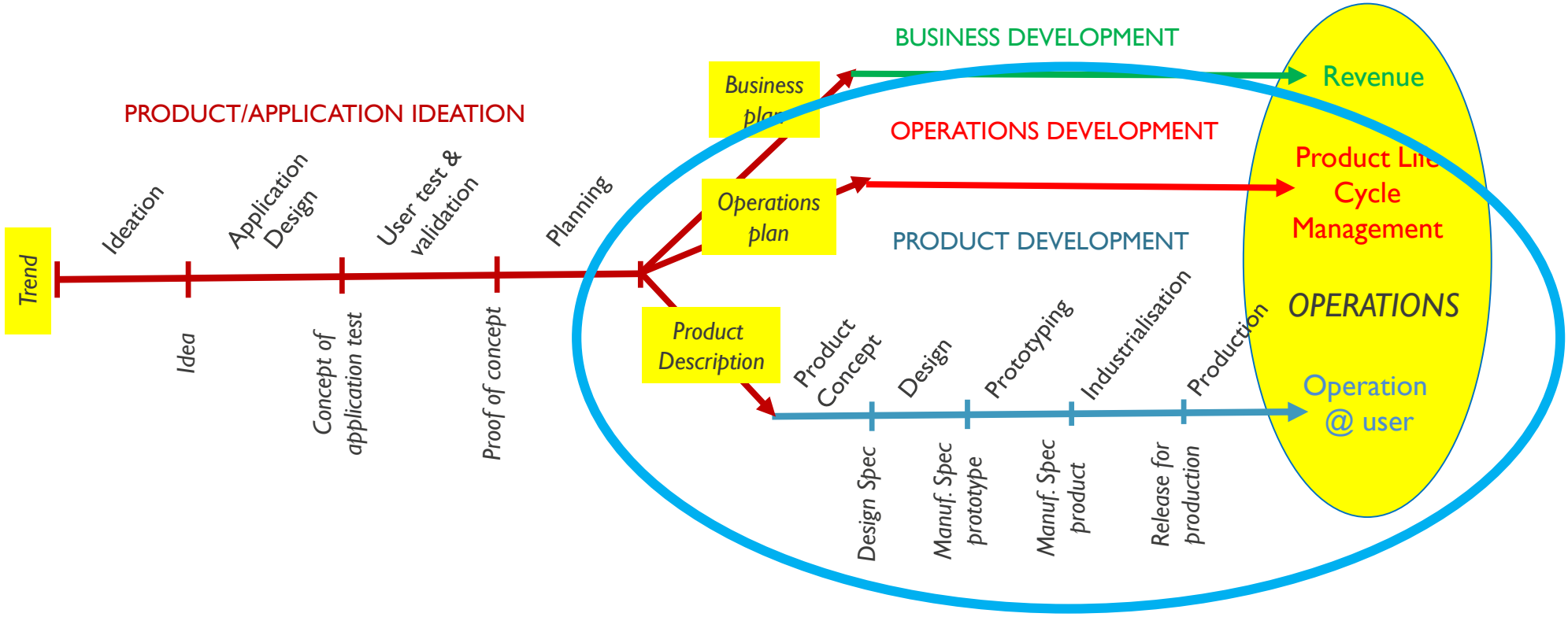
PRODUCT DEVELOPMENT REQUIREMENTS FOR THE "SMART WORLD"

- Use of new devices with little use history
- System adaptable to
  - Different applications
  - Different environments and mission profiles
  - Different volumes, markets (consumer, professional, safety critical), product life cycles
  - All this may be variable over time for the same product
- High quality, high reliability, low maintenance in often "hostile" environments
- Short time-to-market: fast development, scale-up and deployment
- Lowest possible cost

NEW PRODUCT INTRODUCTION FOR THE "SMART WORLD"

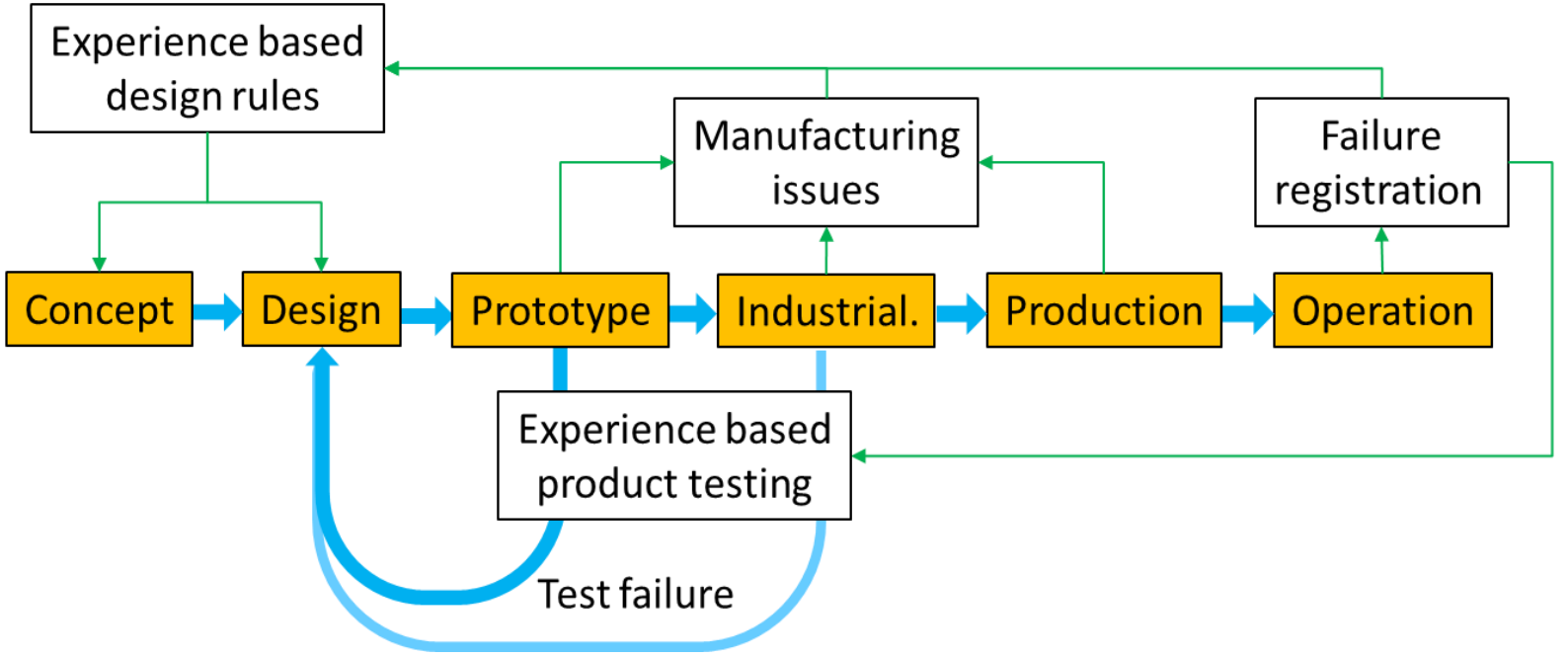
NEW PRODUCT INTRODUCTION FOR THE SMART WORLD

FROM IDEA TO SUCCESFULL BUSINESS



NEW PRODUCT INTRODUCTION FOR THE SMART WORLD

THE TRADITIONAL WAY



New, fast, adaptable, reliable, low cost ... ←→ experience based time-consuming design iterations

NEW PRODUCT INTRODUCTION FOR THE SMART WORLD

WHAT DO WE NEED?

Product:

- Dynamical
- High Quality
- High Reliability
- Low Cost
- Time-to-market

Trustworthy PREDICTION of all Product Life Cycle aspects

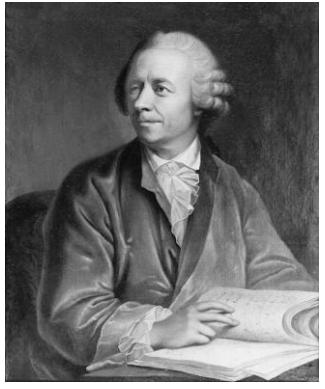
without costly, time-consuming prototyping, testing and design iterations

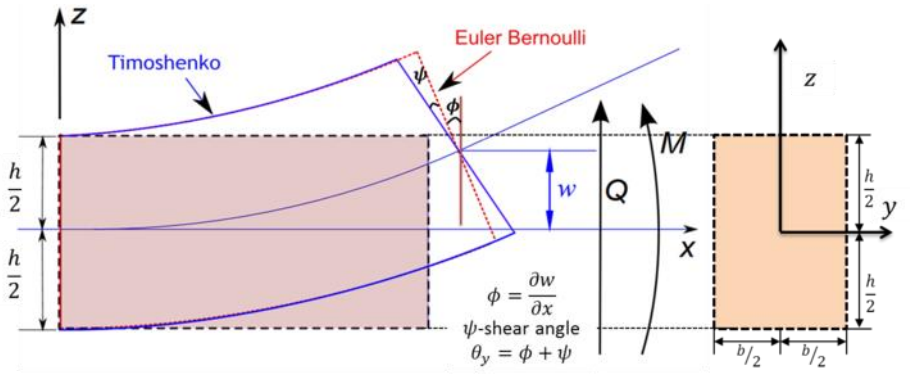
How do we do that?

NPI FOR THE SMART WORLD

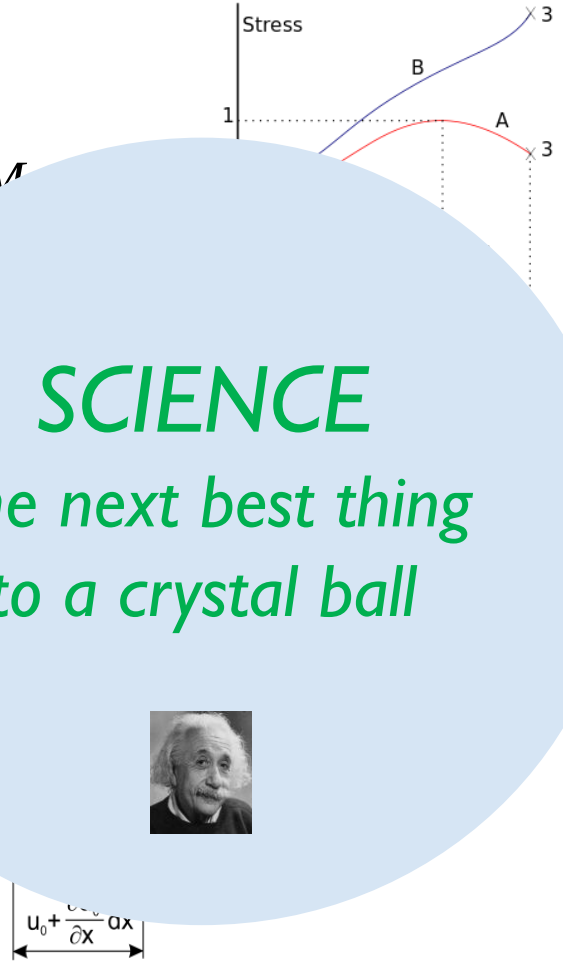
A PRACTICAL WAY







The Mechanics of Electronics

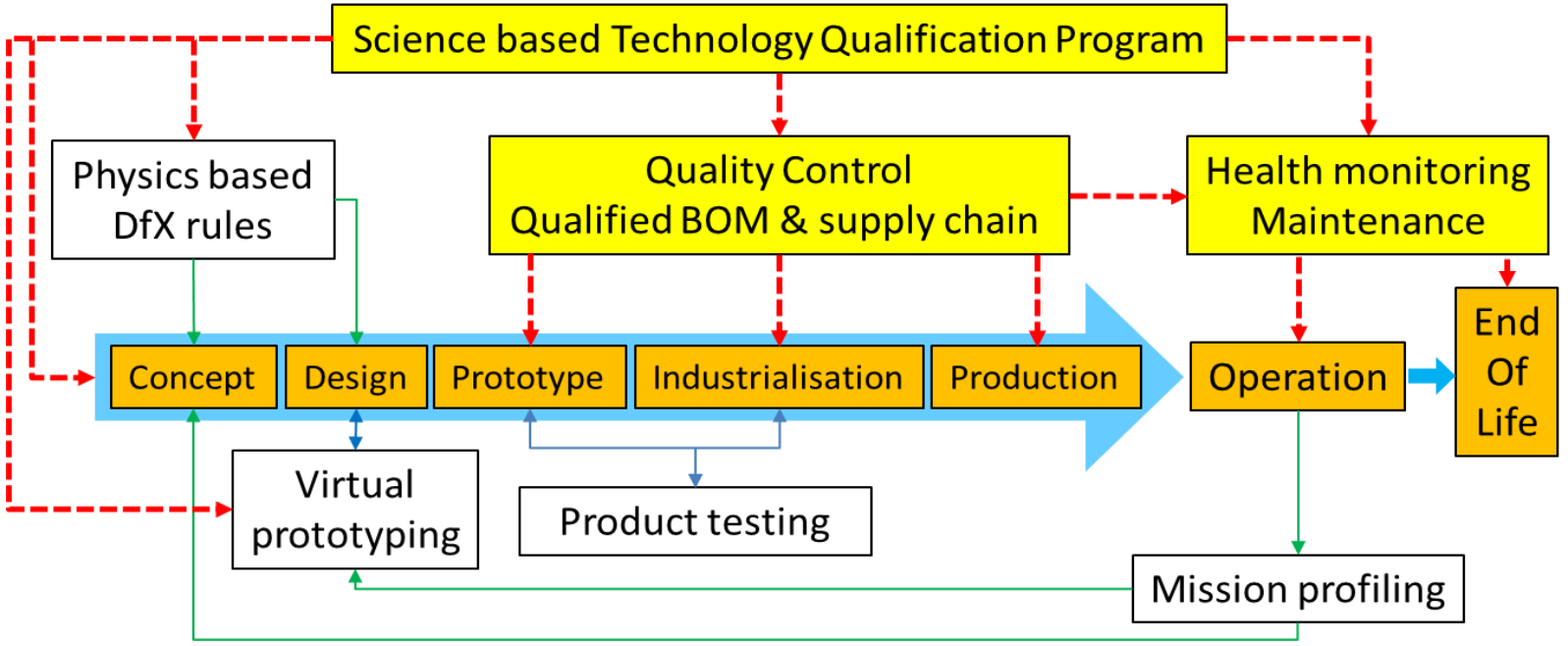


SCIENCE

The next best thing to a crystal ball

NEW PRODUCT INTRODUCTION FOR THE SMART WORLD

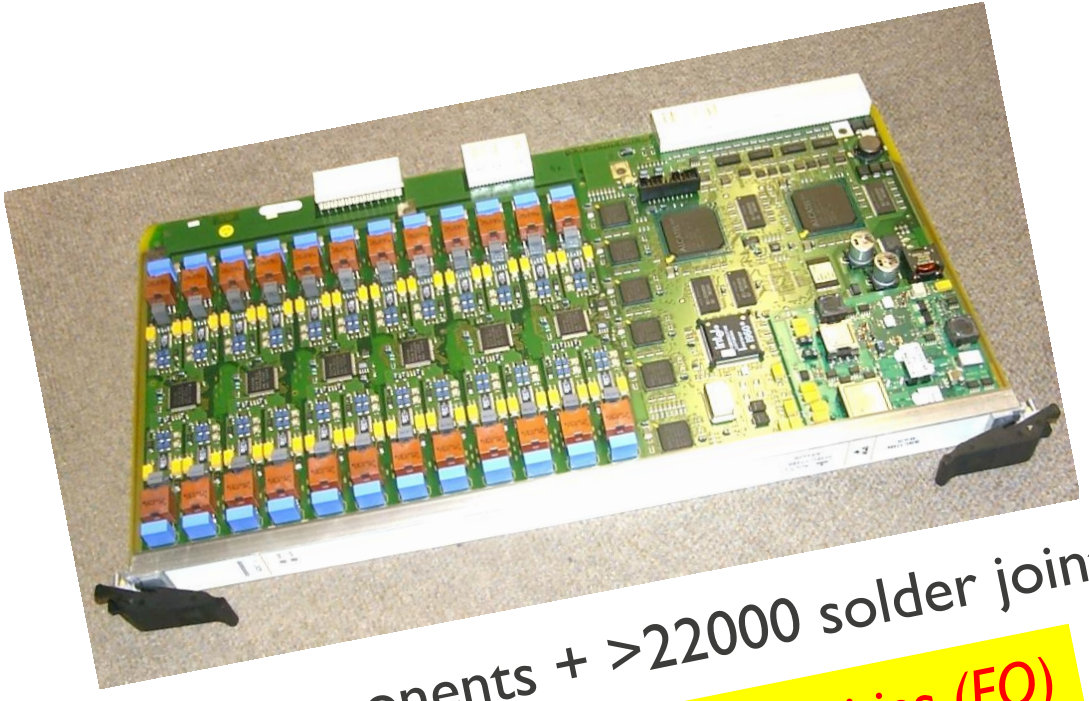
SCIENCE-BASED NPI: A PARADIGM SHIFT



THE RELIABILITY PREDICTION CHALLENGE

THE RELIABILITY PREDICTION CHALLENGE

SO MANY THINGS CAN FAIL ...



2500 components + >22000 solder joints

= >40000 failure opportunities (FO)

Components

Solder joints

PCB

PBA

1 PBA =(1K to 100K FO)
x *n* failure mechanisms/FO

RELIABILITY PREDICTION

THE TRADITIONAL APPROACH: RELIABILITY PREDICTION STANDARDS

MIL-HDBK-217 - *the oldest, best-known most outdated (1995)*
Telcordia SR-332 - *previously Bellcore, telecommunication, US.*
IEC-61709/SN 29500 - *Siemens, industrial, Germany.*
IEC-TR-62380/Fides 2009 - *French industry, industrial-avionics, France.*
217plus – *Quanterion, commercial MIL-HDBK-217 update, US.*
GJB/Z 299C – *China.*

Describe how to determine the reliability of a **system of** electronic **components** using **constant failure rate statistics** and field failure data.

Basic principle: $\lambda_{sys} = \lambda_1 + \lambda_2 + \lambda_3 + \ldots + \lambda_n + \lambda_{PCB}$

RELIABILITY PREDICTION

CONSTANT FAILURE RATE: WHAT DOES IT MEAN?

Buy NEW

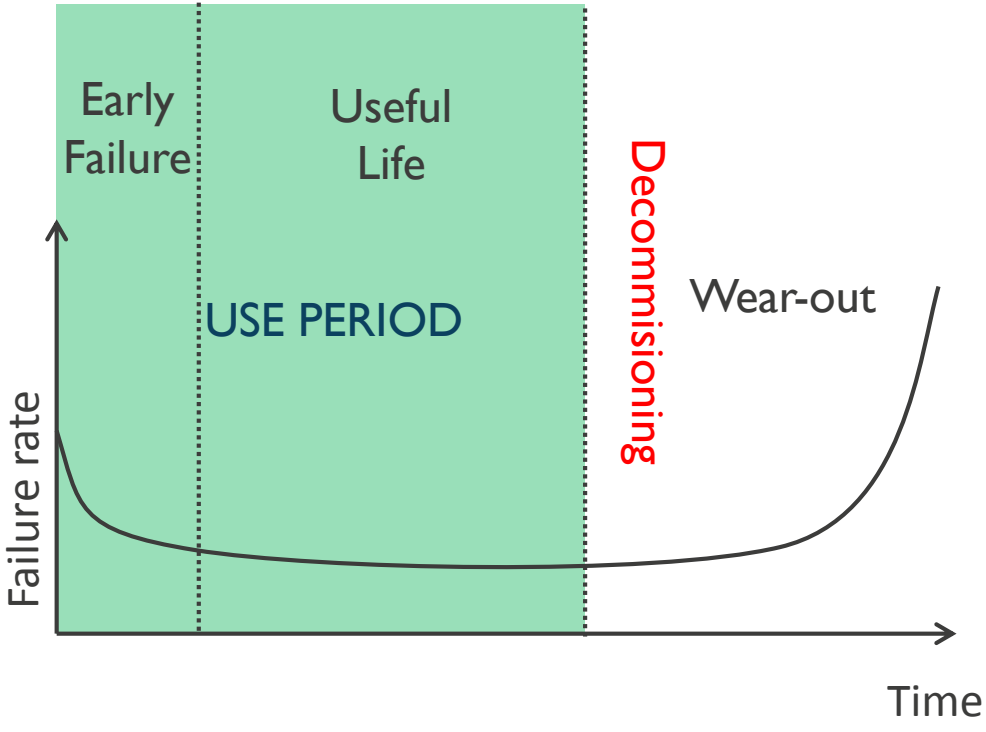
Buy USED

Do you expect the same failure rate for a used car as for a new one?

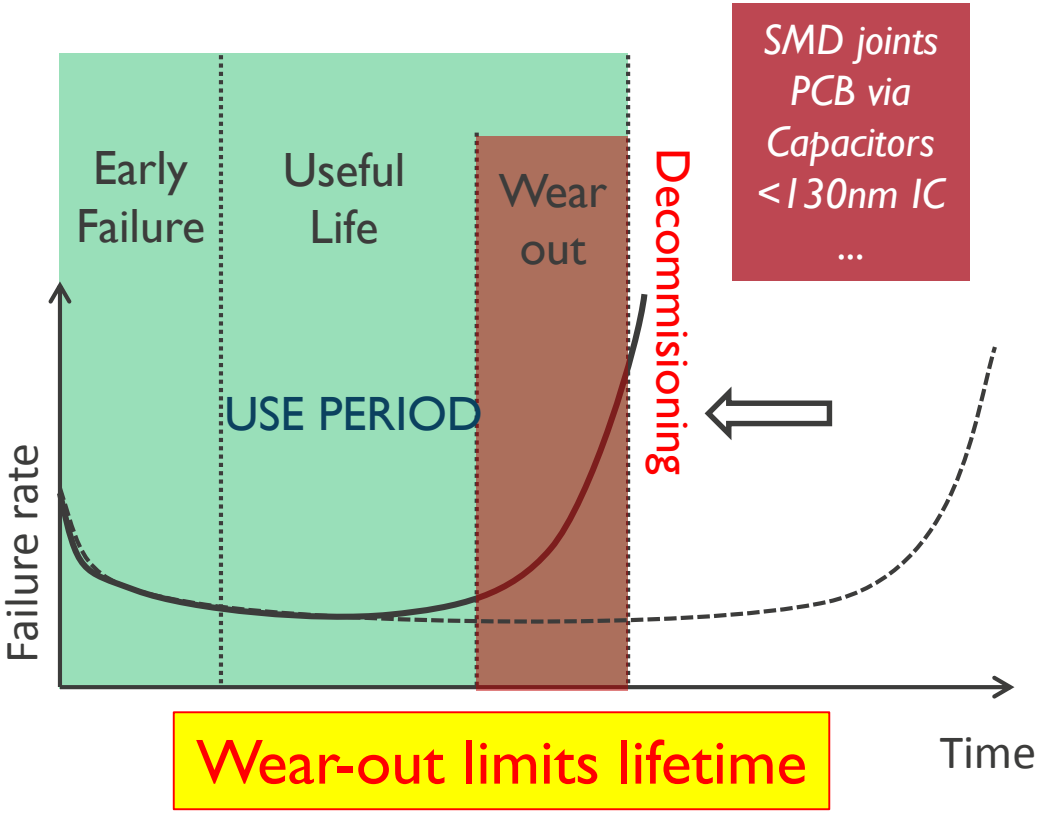
RELIABILITY PREDICTION

THE REAL WORLD

What it was (before the '80s)



What is now!



Army 1995 Memo Prohibiting Further Use of MIL-HDBK-217 Actuarial Reliability Prediction Methods

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH DEVELOPMENT AND ACQUISITION

General Motors Reliability Policy

"... GM concurs and will comply with the findings and policy revisions of Feb. 15, 1996 by the Assistant Secretary of the U.S. Army for Research, Development and Acquisition. … Therefore: Mil-Hdbk 217, or a similar component reliability assessment method such as SAE PREL, **SHALL NOT BE USED**."

GM North American Operation,
Technical Specification Number: 10288874, June 4, 1996.

define the quantitative reliability requirements. The extent to which failures and usage conditions are defined should be determined on an acquisition-specific

Predictions Methods in the 1990s.

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U. S. Military View of Mil-Hdbk-217

"… Mil-Hdbk-217, Reliability Prediction of Electronic Equipment, **and progeny**, is not to be used as it has been shown to be unreliable and its use can lead to erroneous and misleading reliability predictions."

October 1994

Decker, Assistant Secretary of the Army (Research, Development, and Acquisition), Memorandum for Commander, U.S. Army Material Command, Program Executive Officers, and Program Managers

More than 20 years ago but still used!

RELIABILITY PREDICTION
THE PHYSICS-OF-FAILURE APPROACH

A science-based approach to reliability that uses modeling and simulation to design-in reliability.

It helps to understand system performance and reduce decision risk during design and after the equipment is fielded. This approach **models the root causes of failure** such as fatigue, fracture, wear, and corrosion.

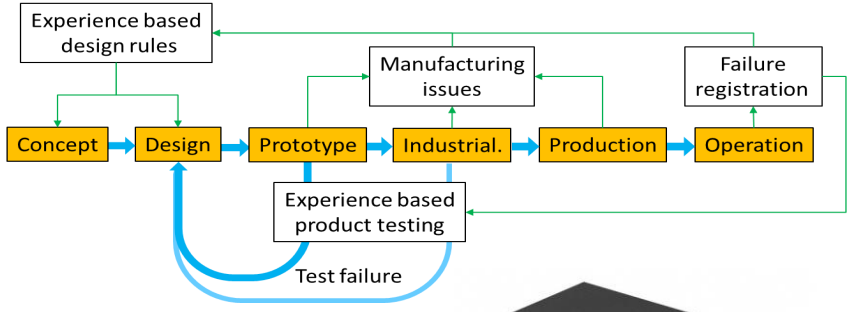
An approach to the design and development of reliable product to prevent failure, based on the knowledge of root cause failure mechanisms. The Physics of Failure (PoF) concept is based on the **understanding of the relationships** between requirements and the physical characteristics of the product and their variation in the manufacturing processes, and the **reaction of product elements and materials to loads (stressors)** and interaction under loads and their influence on the fitness for use with respect to the use conditions and time.

RELIABILITY PREDICTION
THE BASICS OF RELIABILITY PHYSICS

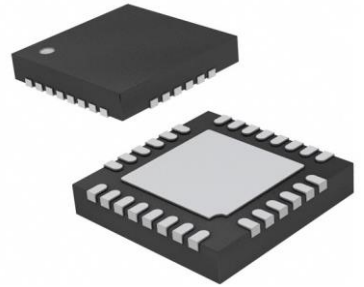
1. Quantitative physical model of the failure mechanism.
   - Fatigue failure: solder joints, PCB via's & tracks.
   - Diffusion and evaporation of liquids: degradation of Al-capacitors.
   - Electro-migration (electric field driven) and corrosion.
   - And many more...
2. Calculation of the stress level dependent "damage factor" determining the lifetime.
3. Apply (empirical) lifetime model: lifetime = F("damage factor")
   (e.g. Wöhler curve)

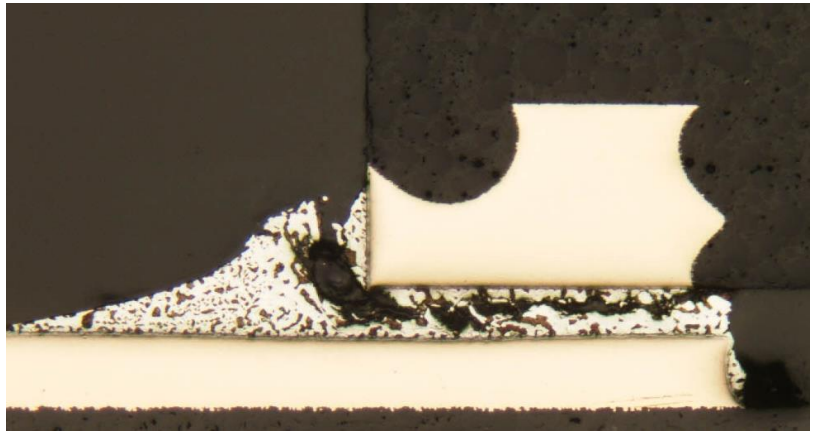
A SMART NPI (RELIABILITY) EXAMPLE

SMART NPI: QFN IN AUTOMOTIVE
TRADITIONAL NPI APPROACH



- First PBA design with 7mm x 7mm QFN (1 month)
- Build PBA (12 weeks incl ordering)
- Qualification: 1500 cycles -40°C to150°C (1 month)
  PBA failure: QFN solder joints
- Redesign PBA with other package type (2 wks)
- Build new PBA prototype (12 weeks)
- Qualification (1 month)
  Hopefully it passes...



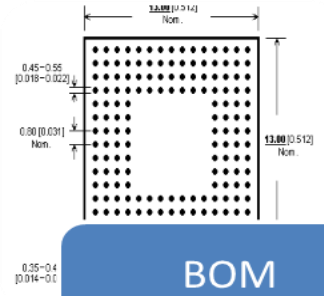


Penalty: +19 weeks time-to-market
+50KEuro material, labor, test

SMART NPI: QFN IN AUTOMOTIVE

SOLDER JOINT FAILURE PREDICTION

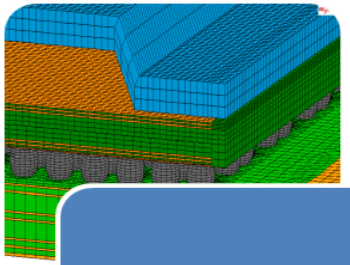
Quantification



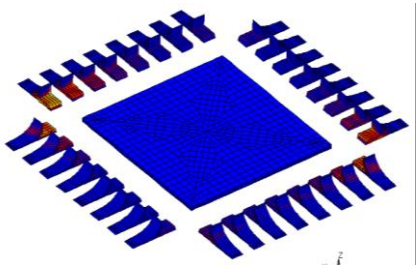
BOM

+

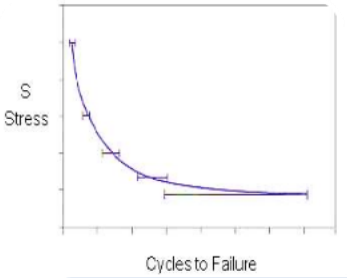
Mission profile



Modelling / Quantification / Simulation



Cyclic strain in solder joints



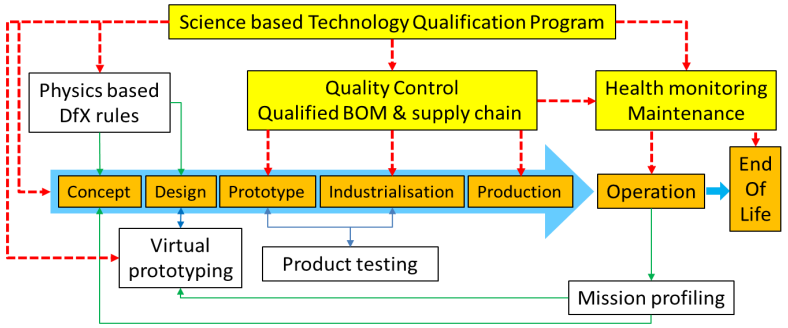
Life time model

SOLDER JOINT RELIABILITY EXAMPLE: QFN IN AUTOMOTIVE

SCIENCE BASED NPI APPROACH

- Qualification of QFN packages for automotive:

  QFN max. 5 x 5mm^2 and mold CTE>8ppm/K
  Thermo-mechanical simulation required for QFN>3mm
- @Design an automotive qualified package is selected
- Virtual prototyping *1500 cycles -40°C to 150°C* (2 d)
  Improve design if necessary (1d – 2 wks) (<10%)
- Build prototype (12 wks)
- Product Qualification test (1 month):
  pass (for Solder Joint)
- Go to industrialization



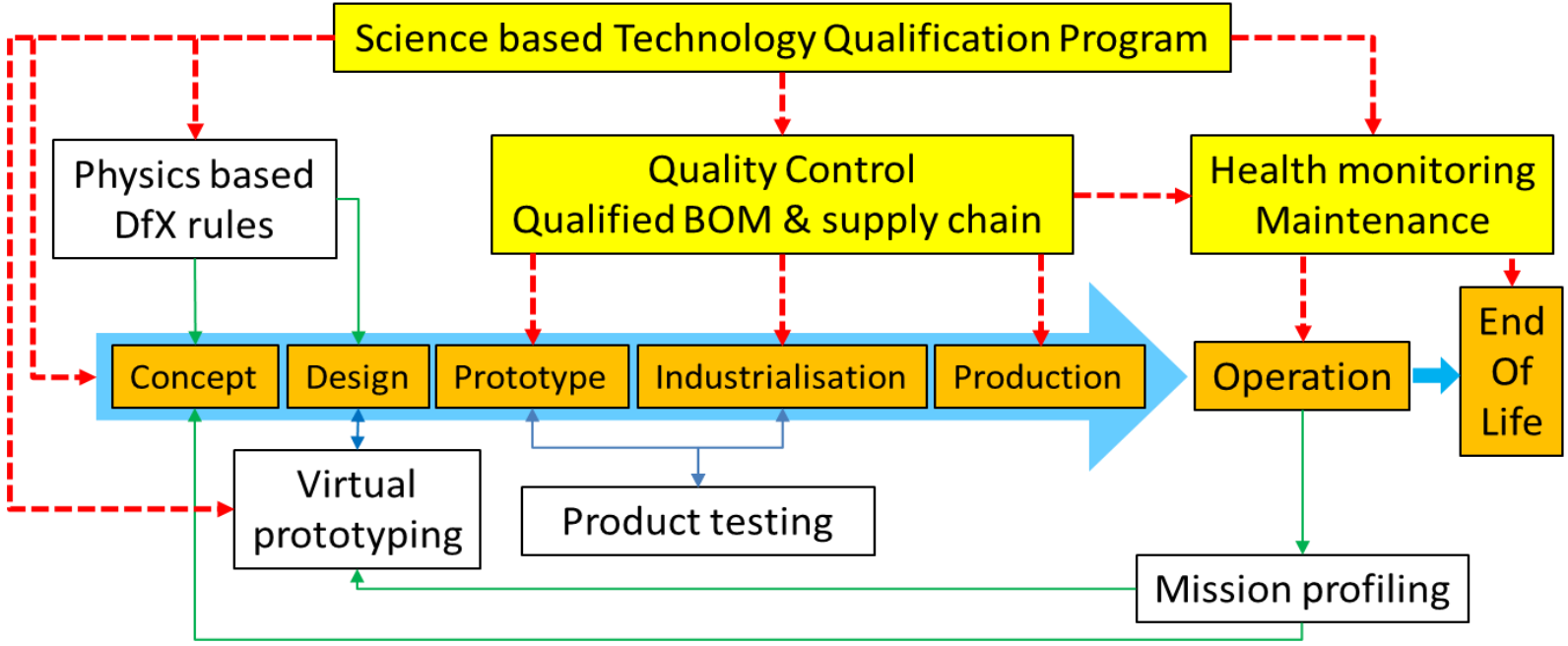
Fail at virtual prototyping penalty (<10%):

- 1 d to 2 wks design effort
  no extra ordering/test delay
- 1 to 5KEuro extra labor
  no extra material nor test cost

10x faster & 10x lower cost
Higher reliability level

NEW PRODUCT INTRODUCTION FOR THE SMART WORLD

CONCLUSION



A Smart World requires **Science-based = Smart** *Design-for-eXcellence, New Product Introduction* and *Product Life Cycle Management*

THANK YOU

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embracing a better life

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