Prognostics and Health Management of Electronics (paper by Vichare and Pecht)

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Schedule

- Explanations and challanges of the implementation of
  - Built-in-tests (BIT)
  - Fuses and Canary
  - Monitoring Precursors to failure
  - Monitoring Environmental and Usage Loads

- PHM Integration

Definitions

Health: extent of degradation or deviation from an expected normal condition

Diagnosis: Detection and isolation of failures

Prognosis: Prediction of a future state, based on the actual and historic conditions

Motivation

Detection of imminent failure in electronic systems.

- Advance warning of failures
- Minimizing unscheduled maintenance, extending maintenance cycles maintaining effectiveness through timely repair actions
- Reducing the life-cycle cost of equipment by decreasing inspection cost, downtime and inventory
- Improving qualification and assisting in the design and logical support of fielded and future systems

For electronic more difficult than for mechanic

Built-in-test

Def.: appliance to identify and locate faults, detect errors including correction circuits, totally self checking circuits and self-verification circuits

BIT software: user can verify the functionality of a system by comparing it with known voltage and data structure

→ Debugging and the conduction of preventive maintenance

Built-in-test: Types

Interruptive BIT (I-BIT): normal equipment operation is suspended during BIT operation (initiated during power-up process or by the operator)

Continuous BIT (C-BIT): equipment is monitored continuously and automatically without affecting normal operation

Periodic BIT (P-BIT): I-BIT system that interrupts normal operation periodically in order to carry out a pseudo continuous monitoring function

Built-in-test III

- System-wide BIT centralized or compromise various BIT centres

- Advantages:
  - Detection of a problem closer to the root
  - Cost-effective assembly and maintenance

- Example: Motorola BIT (M-BIT)

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Fuses and Canaries

http://wallpapers111.com/canary-wallpaper-hd/

Fuses

Definition/Explanation:

Extensions of systems used to disconnect parts of the circuit in case of too much voltage

Examples:

- Thermostats (that stop the heating)
- „normal“ fuses (that disconnect the electric supply of a room/apartment if too many electric devices are connected to the outlets)

Canaries

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Why „Canary“?

→ coal mines, canary is more sensitive to gas than humans. If the canary got sick, the workers had to leave.

http://wallpapers111.com/canary-wallpaper-hd/

- Effective and easy to interpret

Cells, that are precalibrated to fail earlier than the system and „detect“ therefore a failure

Time until the „real failure“ calibratable

Scaling: controlled increasing of the current density within the cells/voltage

→ increased heat → increased degradtion

Canaries

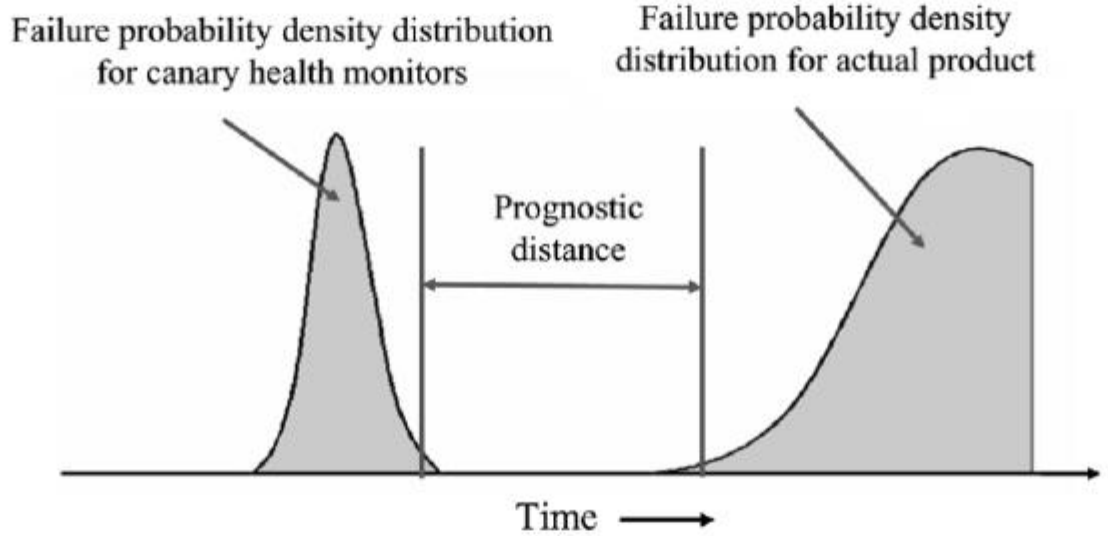

Fig. 1. Advance warning of failure using canary structures.

Canaries: Disadvantages

Later costly, as for older systems a requalification is needed

→ hard to implement in law

Open questions:

1. If the monitoring circuit is replaced, what is the impact after reenergizing?
2. Which protective architecture is appropriate for after reparations?
3. What maintenance policy has to be documented and followed if there is or is no failure secure protective architecture?

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Monitoring Precursors to Failure

Def. Precursor: event that predicts failure

→ change in measurable variable that can be correlated to failure (shift in output voltage or energy support)

causal link between measurable variable and failure

First step: Identify the crucial life circuit parameters to monitor them

Precursors

Methods for identification of the relevant parameters:

1. by factors that are crucial for security, or that may end in catastrophes... USW
2. by past experience
3. by field failure data on similar products
4. by qualification testing
5. by failure mode mechanisms and effects analysis (more systematic)

Precursors

Example parameters proposed by Born, Poenning and Pecht

Demonstration of the potential of select parameters to be viable for the detection of incipient failures was shown through testing

TABLE I
POTENTIAL FAILURE PRECURSORS FOR ELECTRONICS

Electronic Subsystem	Failure Precursor Parameter
Switching power supply	- DC output (voltage and current levels) - Ripple - Pulse width duty cycle - Efficiency - Feedback (voltage and current levels) - Leakage current - RF noise
Cables and connectors	- Impedance changes - Physical damage - High-energy dielectric breakdown
CMOS IC	- Supply leakage current - Supply current variation - Operating signature - Current noise - Logic level variations
Voltage controlled oscillators	- Output frequency - Power loss - Efficiency - Phase distortion - Noise
FET	- Gate leakage current/resistance - Drain-source leakage current/resistance
Ceramic chip capacitors	- Leakage current/resistance - Dissipation factor - RF noise
General purpose diodes	- Reverse leakage current - Forward voltage drop - Thermal resistance - Power dissipation - RF noise
Electrolytic capacitors	- Leakage current/resistance - Dissipation factor - RF noise
RF power amplifier	- Voltage standing wave ratio (VSWR) - Power dissipation - Leakage current

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Monitoring Environmental and Usage Loads

Idea: Collect data about the time until failure and recalculate it concerning the environment and usage to calculate the time of failure of the product.

The environment of a life circuit of a product consists of different parts, that can shorten the life.

TABLE III
EXAMPLES OF LIFE-CYCLE LOADS

Load	Load Conditions
Thermal	Steady-state temperature, temperature ranges, temperature cycles, temperature gradients, ramp rates, heat dissipation
Mechanical	Pressure magnitude, pressure gradient, vibration, shock load, acoustic level, strain, stress
Chemical	Aggressive versus inert environment, humidity level, contamination, ozone, pollution, fuel spills
Physical	Radiation, electromagnetic interference, altitude
Electrical	Current, voltage, power

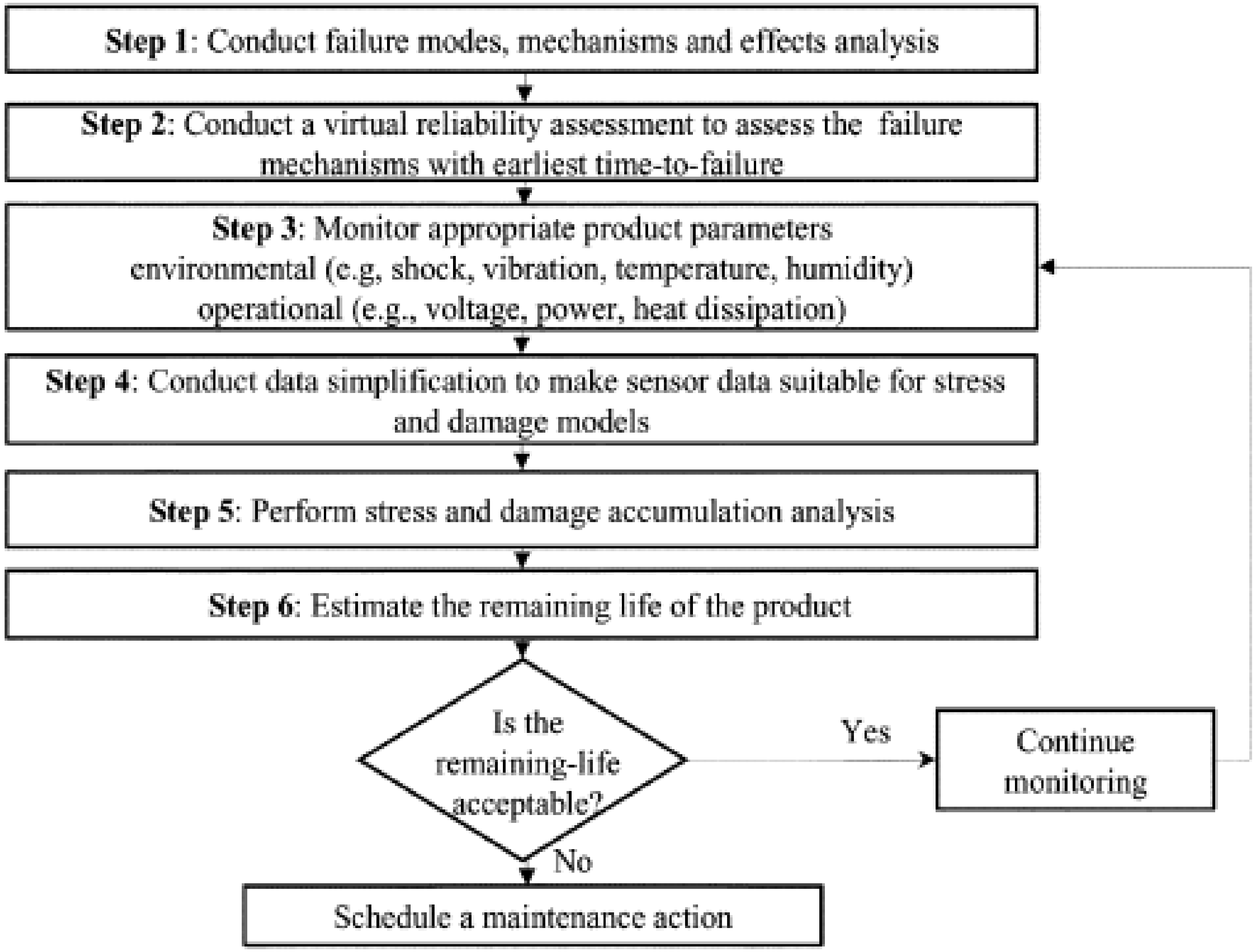

Fig. 3. CALCE life consumption monitoring methodology.

1. Example: Car

- A component board under the hood of a car
- Normal driving in Washington
- On the board 8 surface brackets soldered
- Solder conjunctions identified as dominant failure mechanisms
- Measurement of temperature and vibration

→ Using the LCM method remaining life was predicted accurately

2. Example: Space shuttle

- Space shuttle solid rock booster (SRB)
- Vibration during prestart to calculate the resulting damage
- Using the whole remaining life consumption profil the remaining life was predicted
- → eletronic failure not under 40 missions

- Inside in space shuttle robot arm (vibration and thermal)
- Combination of the damage modells of physic and thermal mechanisms → more 20 years

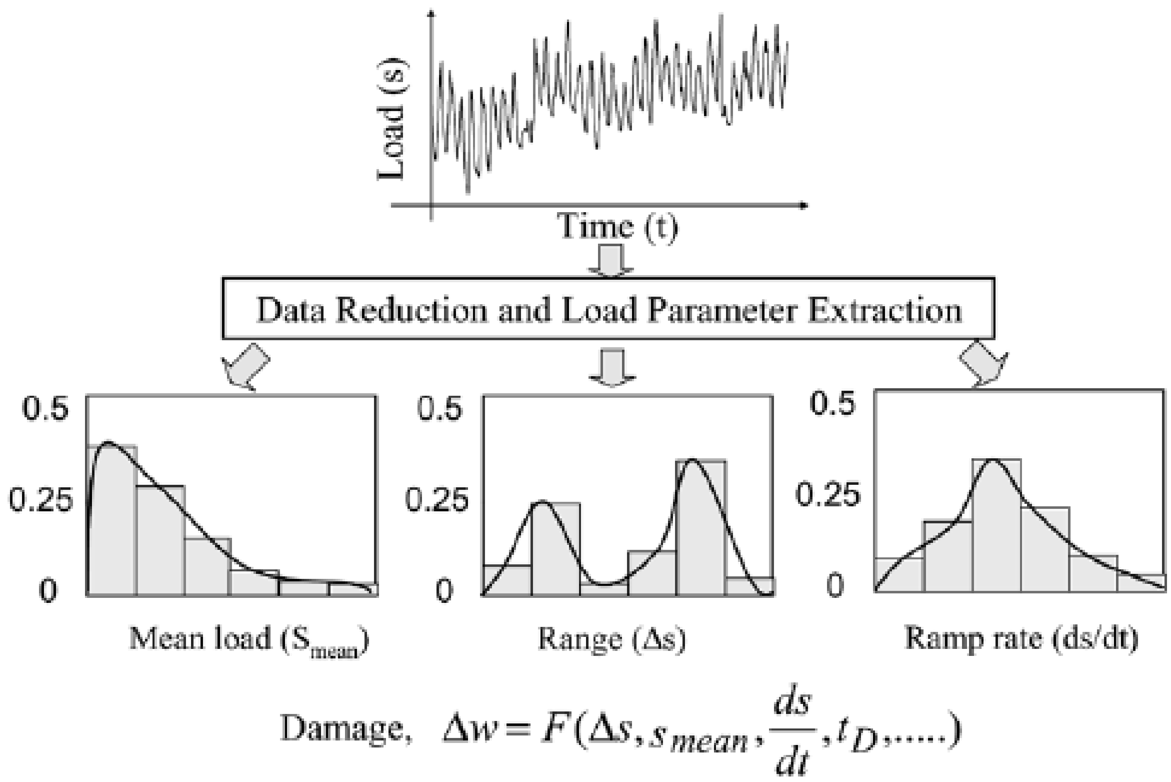

Fig. 4. CALCE PHM using monitored load histories.

The statistical way

- Data mining model for avionic units
- Mean of data like temperature
- Measure them on the flight via time load measurement devices
- Goals:
    - Role of measured environment factors during development of failure
    - Role of combined effects on different factors
    - Probability of failure based on knowledge about suboptimal conditions

- EU founded in 2001 project ELIMA (environmental life-cycle information management and acquisition) for consumer products
- Ways of better managing the life cycles of products using technology to collect vital information during a product's life to lead to better and more sustainable products
- Demonstration through field studies
- ELIMA technique contains sensors and memory to record dynamic data as operational time, temperature and energy consumption
  → game console and household fridge-freezer

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PHM Integration

- An effective PHM integration may include different approaches
- costly analyse to enable a focused monitoring of the weaknesses

Annotations to the paper

Positive:

⊕ examples

⊕ "good" overview over topic

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Negative:

– no explanations of table contents

– too less explanations and definitions