

# Chapter 3

## Failures and Failure Classification

Marvin Rausand  
marvin.rausand@ntnu.no

RAMS Group  
Department of Production and Quality Engineering  
NTNU

(Version 0.1)



**NTNU – Trondheim**  
Norwegian University of  
Science and Technology

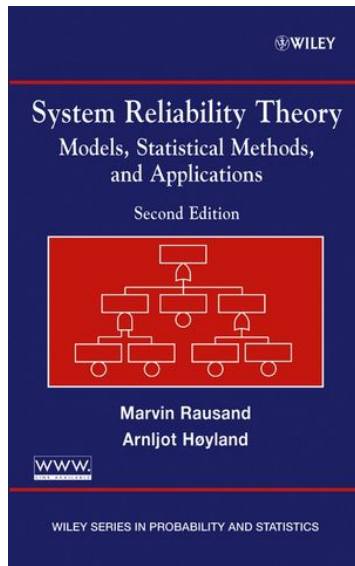
Slides related to the book

System Reliability Theory  
Models, Statistical Methods,  
and Applications

Wiley, 2004

Homepage of the book:

[http://www.ntnu.edu/ross/  
books/srt](http://www.ntnu.edu/ross/books/srt)



# Learning objectives

- ▶ To learn the key terms and concepts related to hardware failures
- ▶ To become familiar with some approaches to failure classification

# Failure - 1

✎ **Failure:** The termination of the ability of an item to perform a required function. [IEV 191-04-01]

A failure is always related to a **required function**. The function is often specified together with a **performance requirement**.<sup>1</sup>

A failure occurs when the function cannot be performed or has a performance that falls outside the performance requirement.

## Shutdown valve

According to the performance requirement, the maximum closing time of a shutdown valve shall be no longer than 15 seconds. A failure of the closing function occurs when the closing time exceeds 15 seconds.

---

<sup>1</sup>Also called a functional requirement

## Failure - 2

A failure is an **event** that occurs at a specific point in time.

It is not always possible to observe when the failure occurs. This may especially be the case when:

- ▶ The function is slowly deteriorating
- ▶ The function is **dormant** (e.g., safety systems)

The failure may sometimes be:

- ▶ Manifested a certain time after the failure occurred (i.e., when the function is demanded)
- ▶ Revealed and corrected before it is manifested (i.e., when the function is tested)

# Fault

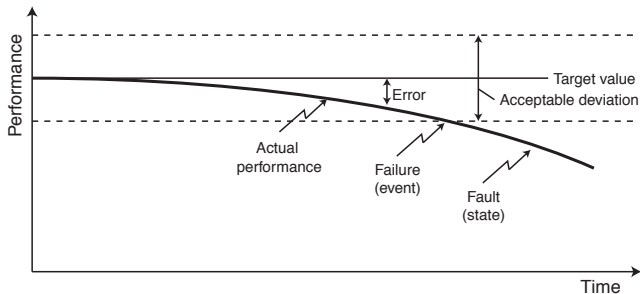
☞ **Fault**: The state of an item characterized by inability to perform a required function [IEV 191-05-01]

Whereas a failure is an event that occurs at a specific point in time, a fault is a **state** that will last for a shorter or longer period.

In most cases, an item will have a fault after a hardware failure has occurred – and we say that the item is in a **failed state**.

Design and installation errors may also prevent the item from performing its required function. The item has a fault that is not preceded by any hardware failure and we call this fault a **systematic fault**.

# Failure, fault, and error



- 👉 **Error:** A discrepancy between a computed, observed or measured value or condition and the true, specified or theoretically correct value or condition

[IEC 60050-191]

# Functions

- ▶ To identify all potential failure modes of an item, we need to identify all the functions of the item, and the associated performance requirements
- ▶ Even “simple” items may have a high number of functions that are difficult to identify
- ▶ Try, for example, to identify all the functions of a mobile phone





## Function categories

It may sometimes be useful to have a list of general function categories (examples for a water pump):

- ▶ Essential functions (e.g., pump water)
- ▶ Auxiliary functions (e.g., contain water - prevent leakage out)
- ▶ Protective functions (e.g., prevent sparks from electro-motor)
- ▶ Information functions (e.g., measure internal pressure, temperature)
- ▶ Interface functions (e.g., connect to in/out pipes)
- ▶ Superfluous functions (e.g., functions remaining after the system has been modified)

# Failure mode - 1

✎ **Failure mode:** The way a failure is observed on a failed item. [IEC 191-05-22]

A failure mode is the way in which an item could fail to perform its required function. An item can fail in many different ways – a failure mode is a description of a possible state of the item after it has failed.

## Pump

Performance requirement: The pump must provide an output between 100 and 110 liters per minute.

Associated failure modes may be:

- ▶ No output
- ▶ Too low output
- ▶ Too high output
- ▶ Too much fluctuation in output

## Failure mode - 2

- ▶ A failure mode is always related to a required function and the associated performance requirement.
- ▶ A failure mode is description of a fault (i.e., a state) and not of a failure (i.e., an event). A more correct term would therefore be **fault mode**<sup>2</sup>
- ▶ Some data sources list, for example, corrosion as a failure mode. This is wrong. Corrosion is a **failure mechanism** and may be a cause of a failure mode. It is, however, not a description of a lost function.

---

<sup>2</sup>This term is used in IEC 60300, but failure mode is so common that a change of the term might confuse the users.

# General failure modes

1. Failure during operation
2. Failure to operate at a prescribed time
3. Failure to cease operation at a prescribed time
4. Premature (spurious) operation

[BS 5760-5]

## Failure modes of a water tap

- ▶ Fail to open (on demand)
- ▶ Fail to close (on demand)
- ▶ Cannot fully open
- ▶ Fail to regulate flow
- ▶ Leakage through (dripping)
- ▶ Leakage out (from tap seals)
- ▶ Fail to regulate temperature
- ▶ Etc.

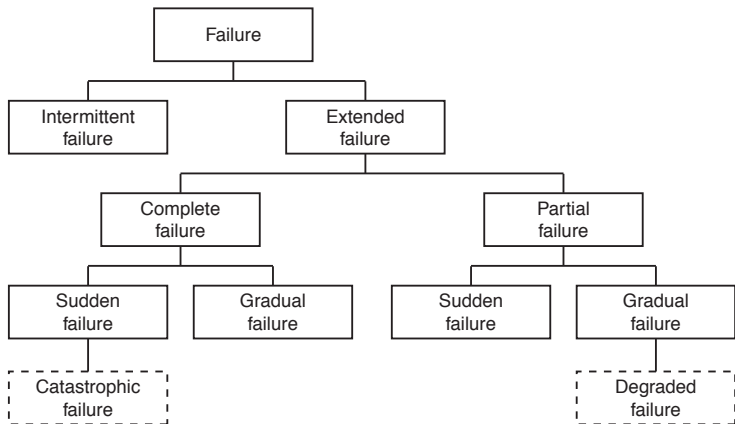


# Failure classification - 1

Failures may be classified according to:

- ▶ Failure causes
  - Primary failure (inherent weakness failure)
  - Secondary failure (overstress or misuse failure)
  - Command fault
- ▶ Time of failure
  - Sudden failure
  - Gradual failure
- ▶ Detectability
  - Evident failure
  - Hidden failure
- ▶ Degree of failure
  - Partial failure
  - Complete failure

## Failure classification - 2



## Failure cause - 1

- ✎ **Failure cause:** The circumstances during design, manufacture, or use which have led to a failure.

IEV 191-04-17

Wikipedia gives the following definition:

“**Failure causes** are defects in design, process, quality, or part application, which are the underlying cause of a failure or which initiate a process which leads to failure. Where failure depends on the user of the product or process, then human error must be considered.”



## Failure cause - 2

NUREG/CR-5460 applies the following terms when describing the failure causes:

- ▶ **Proximate cause:** A condition that is readily identifiable as leading to the failure.
- ▶ **Conditioning event:** An event that predisposes a component to failure, or increases its susceptibility to failure.
- ▶ **Trigger event:** An event, usually external to the component, that activates the failure, or causes the transition to the failed state.
- ▶ **Root cause:** The most basic reasons why the component failed, that - if corrected- would prevent recurrence.

# Failure mechanism

- ✎ **Failure mechanism:** The physical, chemical or other process which has led to a failure.

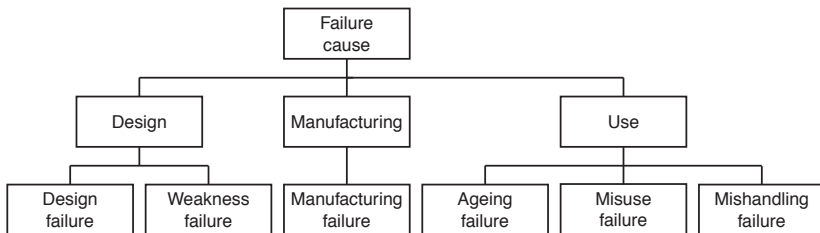
IEV 191-04-18

Examples include:

- ▶ Corrosion
- ▶ Erosion
- ▶ Fatigue
- ▶ Fretting
- ▶ and so on



# Failure cause classification



# OREDA failure classification

The OREDA project classifies failures according to their extensiveness.

## ▶ Critical failure

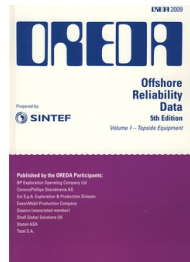
- Sudden failure that causes termination of one or more fundamental functions

## ▶ Degraded failure

- Gradual or partial failure. In time, such a failure may develop into a critical failure

## ▶ Incipient failure

- An imperfection in the state or condition of an item so that a degraded or critical failure can be expected to result if corrective action is not taken



[www.oreda.com](http://www.oreda.com)