INTRODUCTION TO THE CONCEPTS AND THE METRICS IN RELIABILITY ENGINEERING

1. Reliability process and Product Life Cycle
    1. Analysis of the « watch » example
    2. The Product Reliability Assessment Process
    3. Reliability and Product Life Cycle
2. Definitions and Metrics in Reliability Engineering
    1. Definitions
    2. Metrics in Reliability Engineering (Cases of study)

Analysis of the « watch » example

Product definition:

A watch

- Only mechanical (no battery)
- 200m water proof

1. List the different actors in the watch product life cycle
2. What are the expectations of the customer?
3. What are the missions of the « distributor/seller »?
4. How can the manufacturer garantee these objectives at a minimum of cost?

1. Reliability process and Product Life Cycle

The Product Reliability Assessment Process

Objectives
- Needs, System definition, RAMS parameters, Level of the study

Functional Analysis
- Internal and external, Main functions and functional constraints

Design
- Pre-design, technical definition (plans, components), maintenance

Potential Risks Analysis
- Inductives methods: RPA, HAZOP, FMECA, HACCP, Event Trees
- Deductive methods: Fault Tree

Quantitative Risk Assessment
- Static Methods: Reliability Block Diagram, Fault & Event Tress, Expertise, Reliability Standard
- Dynamic methods: MARKOV, Petri Nets, Bayesian Networds

Improvement
- Comparison to the objectives and recommendations, Reliability Growth Models, Safety Barriers, …

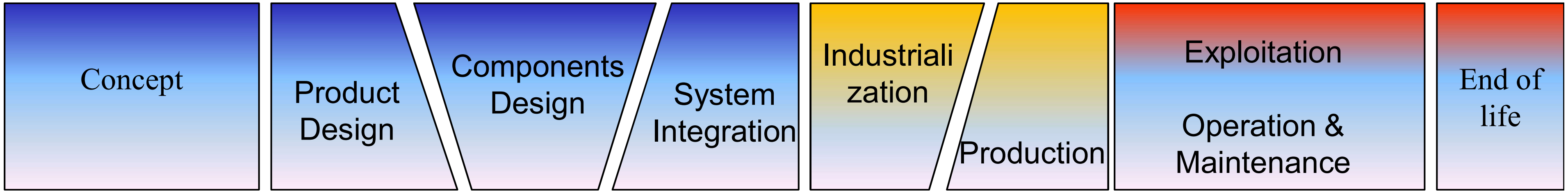
Validation testing on prototype, on pre-series

1. Reliability process and Product Life Cycle

Define the different phases of the product life cycle and give it a representation

1. Reliability process and Product Life Cycle

Reliability and Product Life Cycle

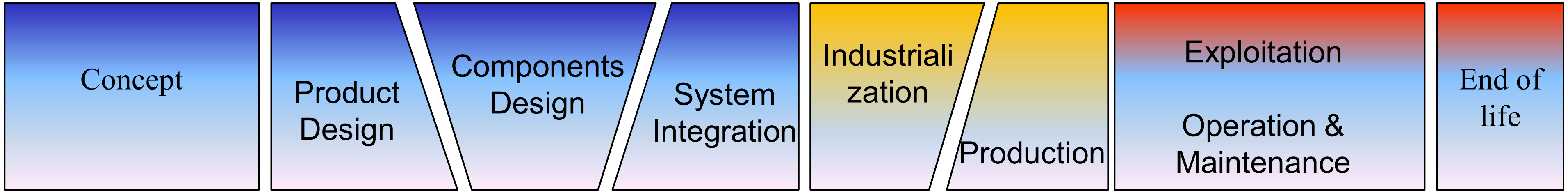


Put in the good place the following metrics :

- Estimated Reliability
- Compared Reliability
- Operational Reliability
- Predictable Reliability

1. Reliability process and Product Life Cycle

Reliability and Product Life Cycle



Reliability Engineering = « The art of studying failures and consequences »
Not a science from the epistemic point of view

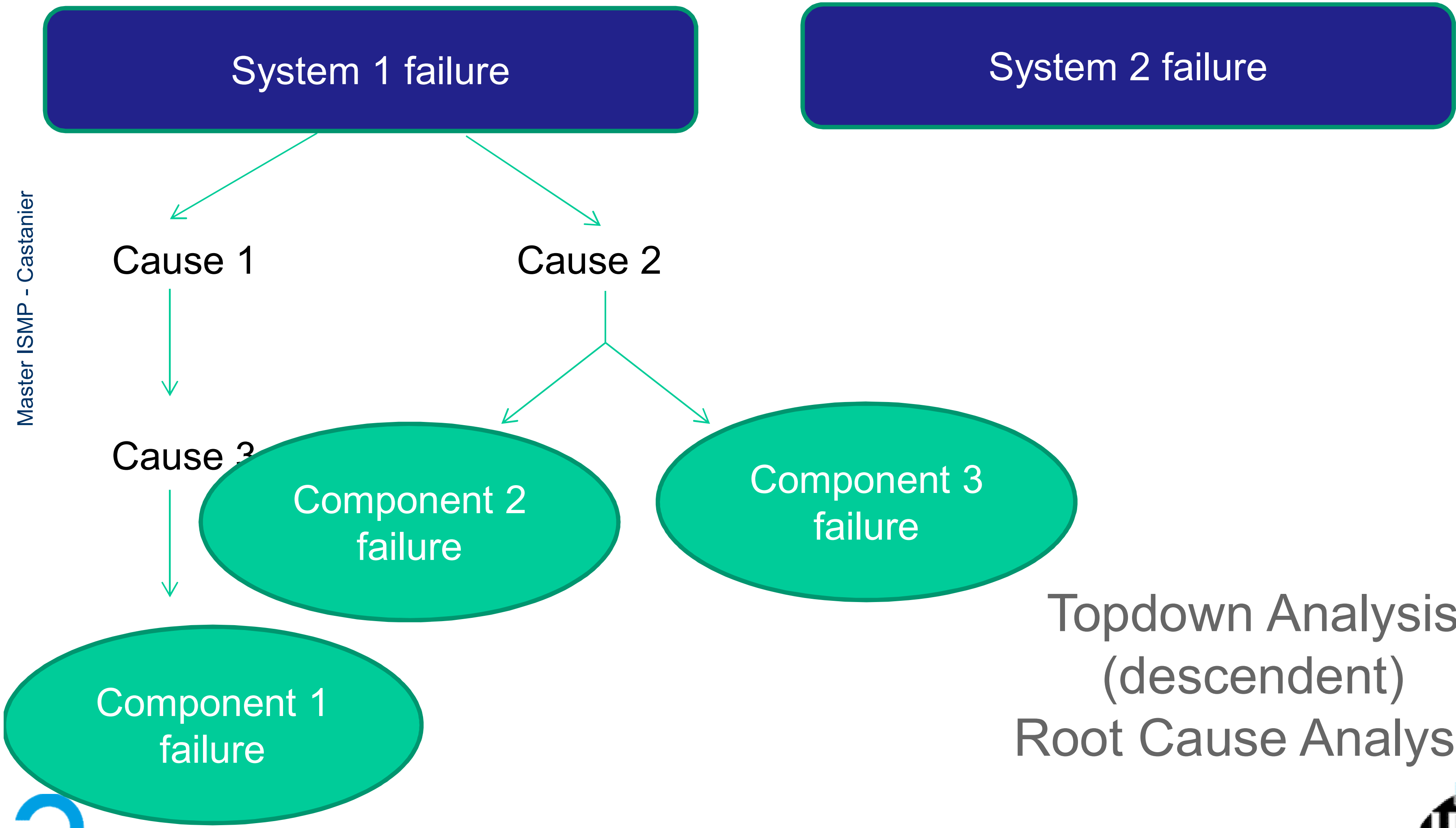
Dependability = The system, product or service capacity to satisfy all of the operational performance required for a given mission.

Dependability *(**IEC 60300**): Combination of capacities of an asset that enable to perform a required function at the appropriate time for the intended duration, without harm for itself and its environment*

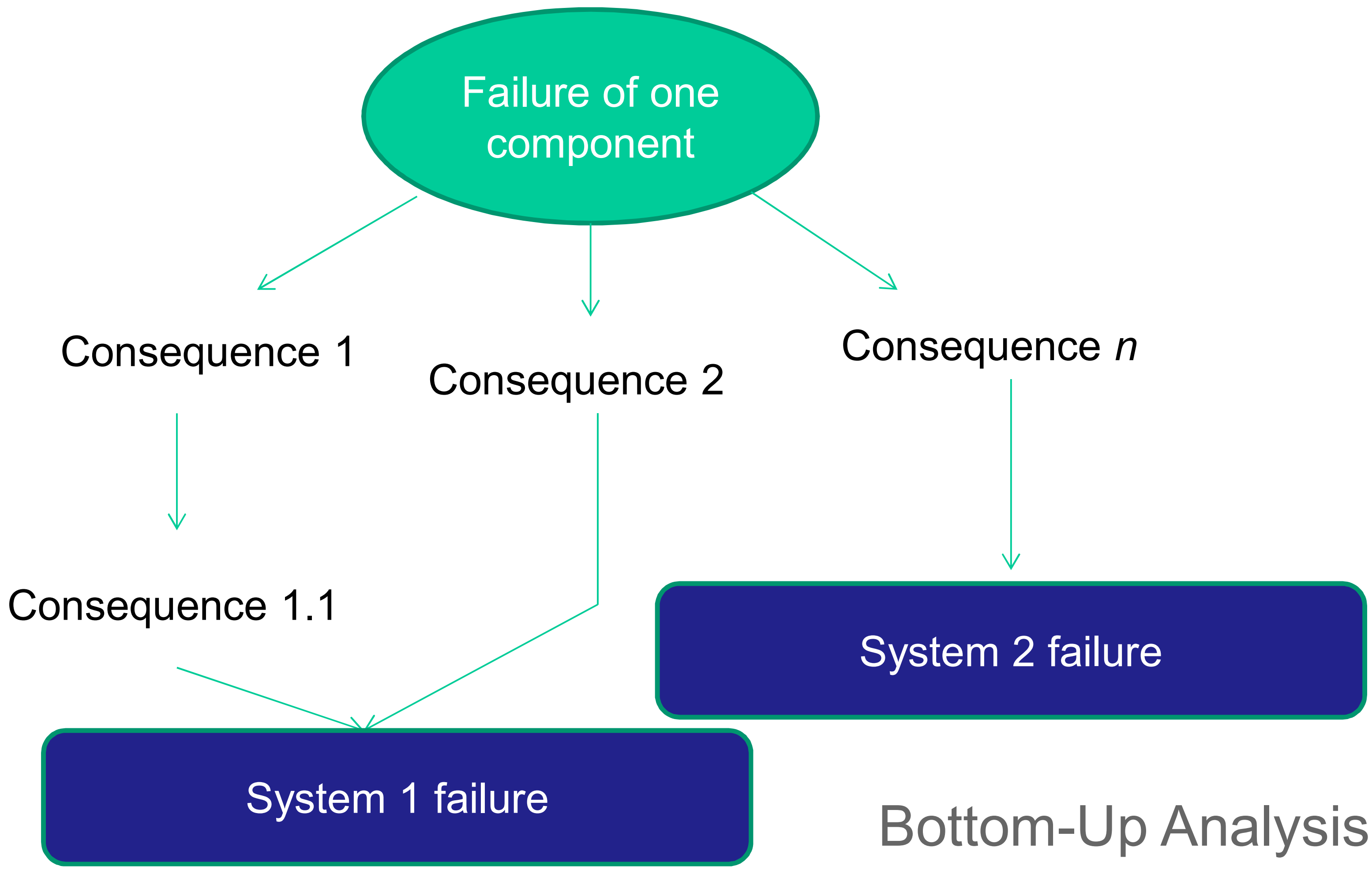
It is the combination of the activities for:

1. Knowing/Listing/Identifying faults
2. Predicting failures
3. Assessing the failures and their impacts
4. Managing the failures (reducing their occurrences and their impacts)

- Failure = Cessation of the ability to perform a required function
- Breakdown = System state after a failure
- Failure mode = Effect by which the failure is observed
- Failure cause = Circumstance(s) related to the design, manufacture or use that caused the failure
  - Failure Mechanism = Physics, chemical, … **process** that caused the failure
  - Error/Defect = affect a part of the system and is a cause of failure (erroneous variable)
  - Fault = cause of the error (shrot-circuit of one component, coding error, …)



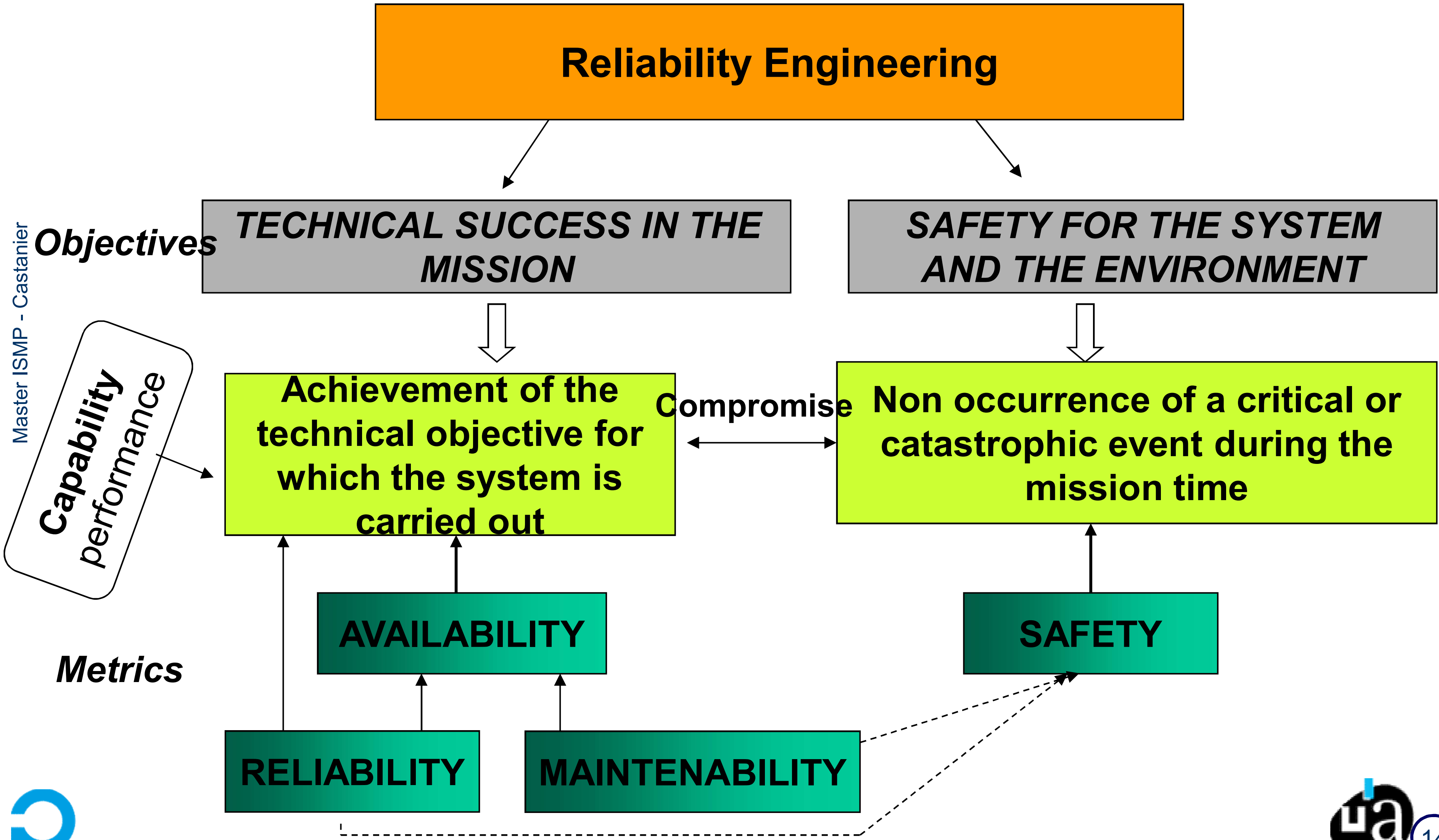
Topdown Analysis
(descendent)
Root Cause Analysis



Bottom-Up Analysis (ascendent)

2. Definitions and Metrics in Reliability Engineering

Introduction to the Metrics

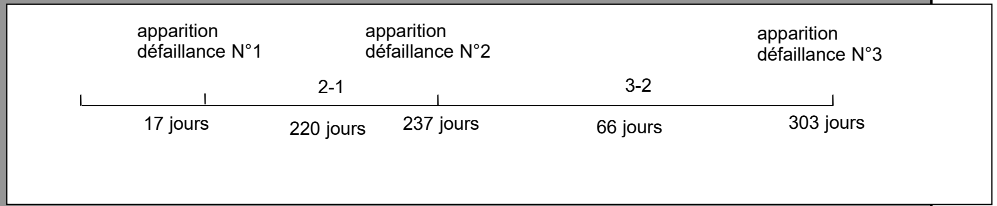


The locotractor

Number of in-service days since first commissing

Number of repairing days for rehabilitation

N°	1	rép.1	02-janv	2	rép.2	03-févr	3	rép.3	04-mars	4	rép.4	05-avr	5	rép. 5	06-mai	6
1	17	3	220	237	2	66	303	6	60	363						
2	345	6	5	350												
3	273	1	70	343	3	16	359									
4	324	1	48	372												
5	28	4	88	116	12	26	142	3	111	253	8	61	314	4	50	364
6	6	11	11	17	5	273	290									
7	39	1	257	296												
8	36	4	328	364												
9	180	8	33	213	1	49	262									
10	273	1	5	278	2	9	287									
11	40	3	313	353												
12	250	1	105	355	2	2	357									
13	135	1	182	317	6	31	348	2	1	349						
14	119	3	95	214												
15	39	3	215	254												
16	229	4	6	235	3	29	264									
17	209															
18	77	7	118	195												
19	179	21	28	207	2	15	222									
20	149															
21	158															
22	47	6	150	197												
23	186															
24	1	11	198	199												
25	3	3	8	11	2	130	141	8	50	191						
26	111															
27	36															
28	98															
29	13	2	22	35												
30	36															
	3636	105	2505		40	646		19	222		8	61		4	50	



Sum

Which kind of information related to operation could you assess from this O&M datasheet?

2. Definitions and Metrics in Reliability Engineering

Metric definitions (1)

MTTF (Mean Time To Failure) : Average operating time before the first failure – It is a metric of the system reliability without taking into account the maintenance effects.

MUT (Mean Up Time) : Average operating time – It is a metric of the system reliability with taking into account the maintenance effects.

MDT (Mean Down Time) : Average time the system is unavailable – It is the capacity assessment of the process to rehabilitate the system. It includes all of the system downtime.

MTTR (Mean Time To Repair) : Average time for the repair action – This is the system maintenability assessment. The MTTR is frequently confused witht the MDT.

MTBF (Mean Time Between Failure) : Average operating time between 2 successive failures – This is the characterization of the overall operating time.

2. Definitions and Metrics in Reliability Engineering

Asymptotic availability (or mean): ratio of operating time and the overall time

Failure rate: expression related to the system or component reliability – It characterizes the instantaneous potential to break down knowing the product is in function

MTBUR (Mean Time Between Unscheduled Repair): Average time between 2 successive corrective maintenance when preventive maintenance is performed.

2. Definitions and Metrics in Reliability Engineering

Metric construction

Case study 2: Database of a car fleet (Failure field data)

Case study 3: Reliability testing (validation/qualification in design phase)

Case study 2: Database of a car fleet

Analysis of a database:

Data in the attached file = Éléments recensés Fiche jointe = Maintenance data for each of 11 vehicules

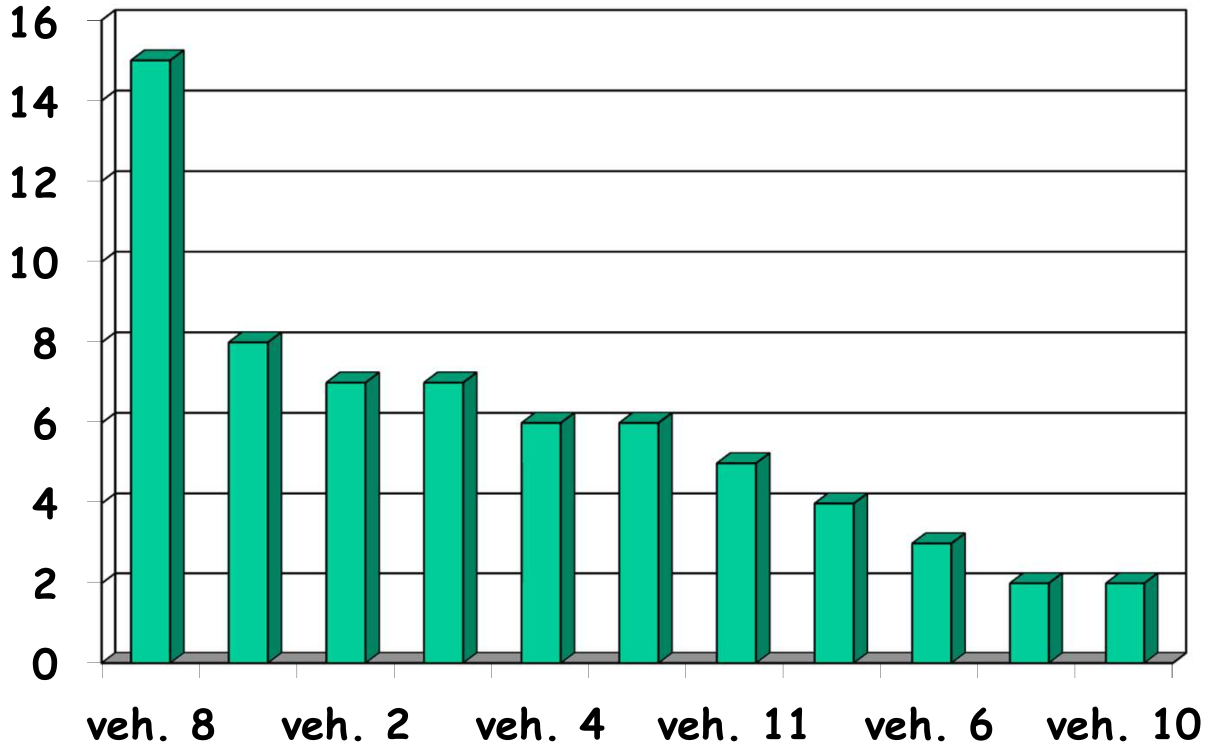
Objectives :

- Identification of the weak points for decreasing costs and unavailability
- Characterization of the failure distribution to assess the economical life time of one vehicle

Analysis process

- Homogeneity of the sample
- Identification of the weak points: Construction of different indicators
- System analysis
- Conclusions

1. Homogeneity study



Vehicle 8 will be taken off the sample

2. Weak points

The objective of the study is to identify the most critical failures in terms of frequency and downtime and to propose some improvement actions.

Define and implement a process for the analyze.

Case study 2: Database of a car fleet

2. Weak points

Case study 2: Database of a car fleet

2. Weak points

Case study 2: Database of a car fleet

2. Weak points

Case study 2: Database of a car fleet

2. Weak points

Case study 2: Database of a car fleet

3. System analysis

Class (10^3km)	Number of vehicles in test	Total number of kms done in the class	Number of failures per class	Number of failures/km/class (10^{-5} def/km)
00-10				
10-20				
20-30				
30-40				
40-50				
50-60				
60-70				
70-80				
80-90				
90-100				
100-110				
110-120				

Case study 2: Database of a car fleet

3. System analysis

Plot the number of failure per km in a class per class

Case study 2: Database of a car fleet (Failure field data)

Case study 3: Reliability testing (validation/qualification in design phase)

Study definition:

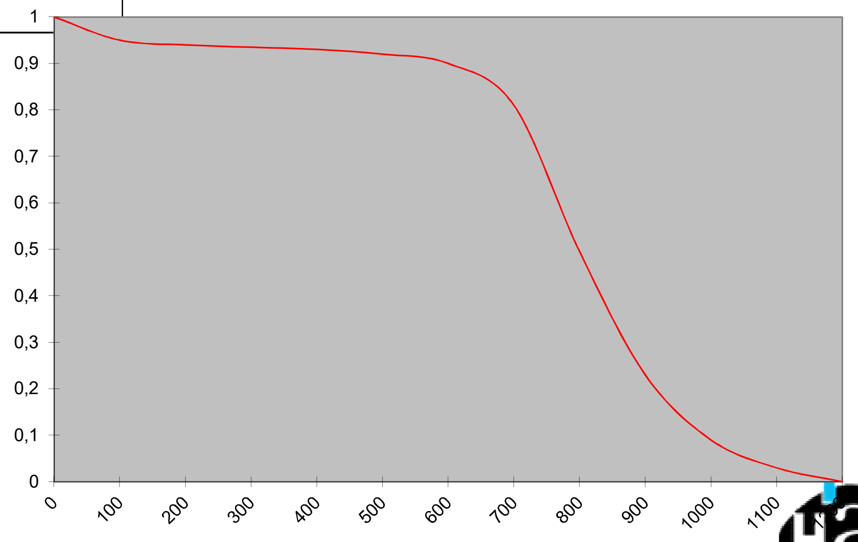
Objective: Characterize the operating/failure times of incandescent lamps

Method: Life time test

- 200 lamps in test
- We note the number of non-failed lamps at the beginning of each of the classes.

N.B. : The devices are not repairable

Test duration (h)	Survivors	% of survivors
0	200	1
100	190	0,950
200	188	0,940
300	187	0,935
400	186	0,930
500	184	0,920
600	180	0,900
700	162	0,810
800	99	0,495
900	46	0,230
1000	18	0,090
1100	6	0,030
1200	0	0,000



Test duration (h)	Survivors	% of survivors
0	200	1
100	190	0,950
200	188	0,940
300	187	0,935
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500	184	0,920
600	180	0,900
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800	99	0,495
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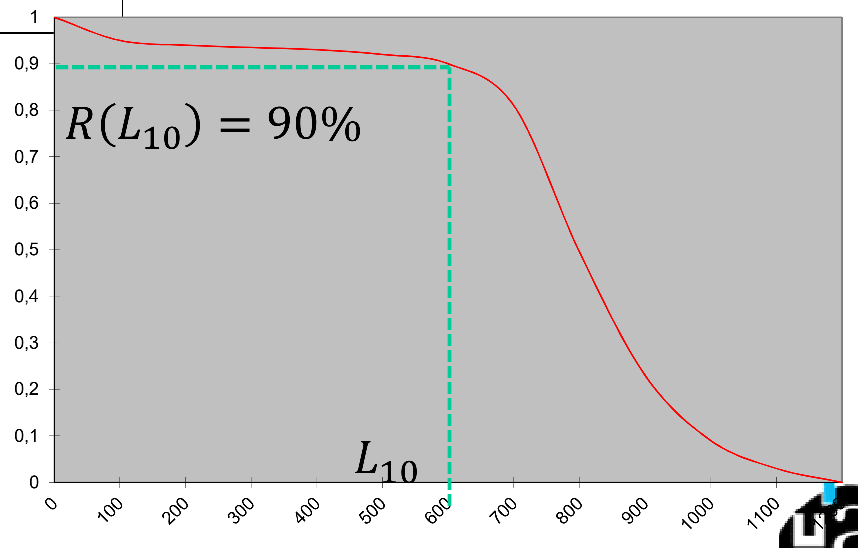
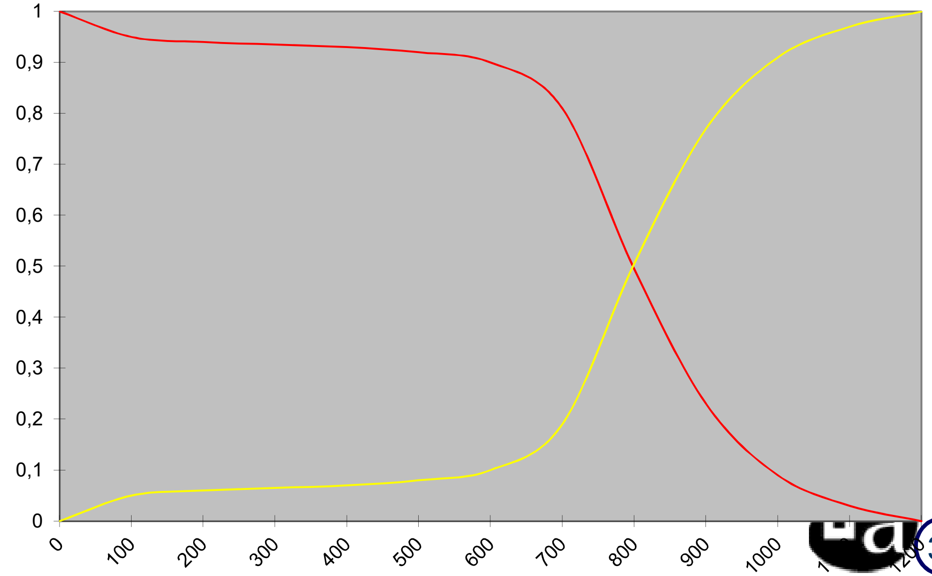
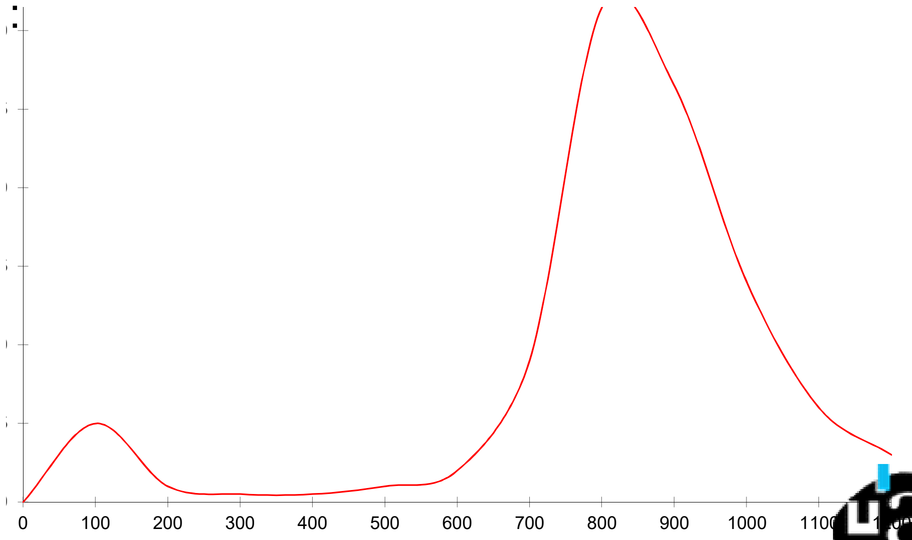
1200	0	0,000



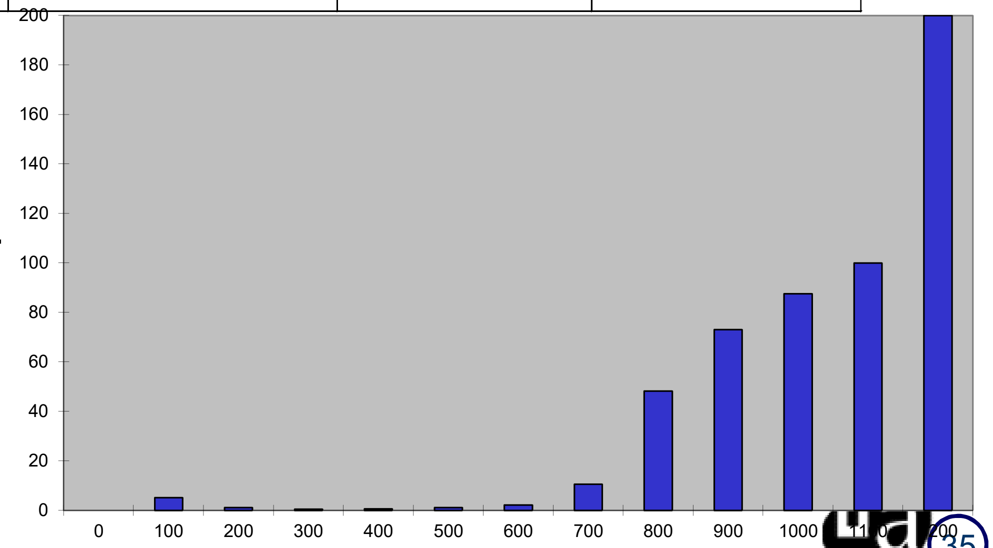
Test duration (h)	Survivors	% of survivors	% of failures
0	200	1	0,00
100	190	0,950	0,050
200	188	0,940	0,060
300	187	0,935	0,065
400	186	0,930	0,070
500	184	0,920	0,080
600	180	0,900	0,100
700	162	0,810	0,190
800	99	0,495	0,505
900	46	0,230	0,770
1000	18	0,090	0,910
1100	6	0,030	0,970
1200	0	0,000	1,000



Test duration (h)	Survivors	% of survivors	% of failures	Nb fail./(h x class)
0	200	1	0,00	0
100	190	0,950	0,050	0,00050
200	188	0,940	0,060	0,00010
300	187	0,935	0,065	0,00005
400	186	0,930	0,070	0,00005
500	184	0,920	0,080	0,00010
600	180	0,900	0,100	0,00020
700	162	0,810	0,190	0,00090
800	99	0,495	0,505	0,00315
900	46	0,230	0,770	0,00265
1000	18	0,090	0,910	0,00140
1100	6	0,030	0,970	0,00060
1200	0	0,000	1,000	0,00030



Test duration (h)	Survivors	% of survivors	% of failures	Nb fail./(h x class)	Failure rate
0	200	1	0,00	0	0
100	190	0,950	0,050	0,00050	5,13.e-4
200	188	0,940	0,060	0,00010	1,06.e-4
300	187	0,935	0,065	0,00005	0,53.e-4
400	186	0,930	0,070	0,00005	0,54.e-4
500	184	0,920	0,080	0,00010	1,08.e-4
600	180	0,900	0,100	0,00020	2,20.e-4
700	162	0,810	0,190	0,00090	10,53.e-4
800	99	0,495	0,505	0,00315	48,28.e-4
900	46	0,230	0,770	0,00265	73,10.e-4
1000	18	0,090	0,910	0,00140	87,50.e-4
1100	6	0,030	0,970	0,00060	100,00.e-4
1200	0	0,000	1,000	0,00030	200,00.e-4



Reliability [IEC 91]

« The reliability, related to the concept of capability of the non-failure is the characteristic of a device expressed by the ability or probability that the device performs a given mission or function under specified operational conditions ».

Reliability = confidence in the device function

$R(t) = Prob(Failure\ time > t) = 1\text{-}F(t)$

Example: A production manager requires that a machine should not failed more than 5 times per week (the corresponding dowtime is at least 20 minutes per failure). This requirement can be rewritten as: One failure can occur per day, in average, over a production week. The technical specification is: the failure probability should be lower or equal to 0,125 per hour, given 8h/day and 5 days/week. »

Maintenability [IEC 91]

« The maintenability, related to the concept of capability of repair is the characteristic of a device expressed by the ability or probability that the device could be repaired in the time interval $[t_0, t_1]$, given the failure at time t_0 ».

Example : 90% of the failures should incur less than 20 minutes of downtime. This takes into account failure detectio, the repair ou the replacement of a part which can come from a spare part stock (which has to be sized in consequence) and the tests.

Availability [IEC 91]

« The availability, related to the concept of capability of usage is the characteristic of a device expressed by the ability or probability that the device should operate at time t_1 ».

Example: Requiring that the availability is greater or equals to 95% in average is equivalent to, during its operational mission, the device should be on-condition at least 95% of the time and during the last 5% it could be failed or in preventive maintenance.

Another requirement could be the device should be available at a given time (for example, after 10h) with a given probability (e.g., $\geq 0{,}99$)

Safety [IEC 91]

« The safety, related to the concept of capability of the non-aggression of persons, goods and environment is the characteristic of a device expressed by the ability or probability that the device performs its mission without circumstances which could cause harms to people, goods and environment. »

Example: For commercial airplanes, the safety goal is « No failure can cause a catastrophic event per 10,000,000 flight hours ». This can be formulated by: « The probability that a catastrophic event should be lower than 10^{-7} per flight hour »