Sûreté de fonctionnement & Retour d'Expériences

Dependability and Feedback Data Collection

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Modalities of Test:

2 Quizes ➔ 20% (Surprise tests)

1 DM ➔ 20 %

1 DS ➔ 60%

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Introduction

Dependability (Sûreté de fonctionnement) : Measure of a system's :

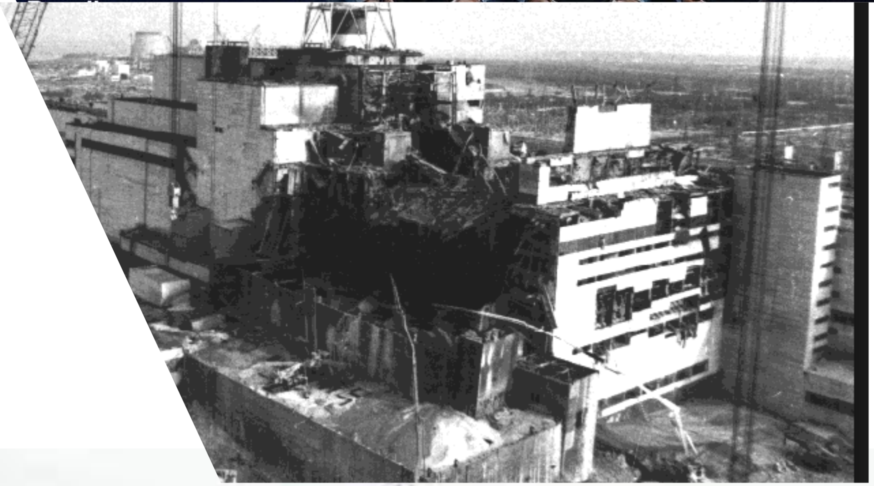
- Reliability (*fiabilité)* : Ability to perform a specific function
- Availability (*disponibilité*) : Ability of system to be kept in a functioning state.
- Maintainability (*maintenabilité*) : Ability of system to be repaired or maintained.
- Safety-Integrity (*sécurité*): Absence of catastrophic consequences on users/environment, Absence of improper/unknown alterations to system functioning.

Dependability = RAMS

Need of reliability

- Space shuttle challenger disaster 1986 :
  - design defects
  - rubber seal became brittle in freezing temp.

- Chernobyl Nuclear Disaster 1986: design defects.
  - design defect, human error,
  - no reliability taken into account.



- Point pleasant bridge disaster (1967): Bridge in West Virginia (USA) collapsed, metal fatigue.

Reliability and Maintainability

Inclusion and growth in academics is motivated by:

- real accidents, quality control,
- consumer awareness, govt. regulations,
- environment friendly, sustainable growth etc.

Gallup poll (1985) by American Society of Quality control

→consumer awareness!

RAMS :

- Design process,
- life cycle costing, cost-benefit analysis,
- inventory, economic optimization,
- maintenance policy selection: preventive or predictive?
- replacement decisions (decision making under multi criteria)

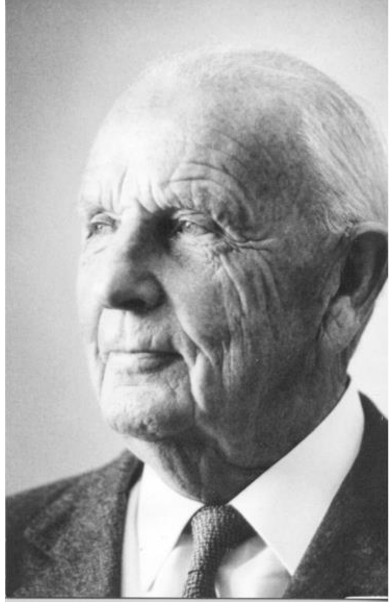
....

Ten most important product attributes

Attribute	Average score
Performance	9.5
Lasts a long time (reliability)	9.0
Service	8.9
Easily repaired (maintainability)	8.8
Warranty	8.4
Easy to use	8.3
Appearance	7.7
Brand name	6.3
Packaging/display	5.8
Latest model	5.4

Source: *Quality Progress*, vol. 18 (Nov.), pp. 12–17, 1985.

History of reliability (not exhaustive):



- 1930 , 1940 : Waloddi Weibull analyzed fatigue life in materials.

- Till 20th century, component parts individually fabricated,
    - reliability mostly dependent upon craftsman/manufacturer and
    - **not** determined by combination of component reliability.

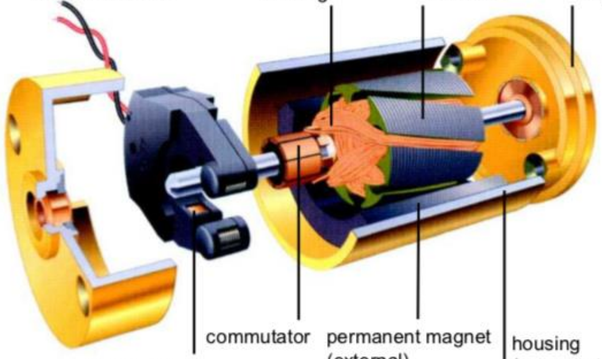
- The advent of the electronic age, accelerated by the Second World War

→ need for more **complex mass-produced component parts with a higher degree of variability** in the parameters and dimensions.

- Emergence of new technologies, lessons from failures → Reliable systems , Reliability engineering.

- Some failure data banks
    - UKAEA (UK Atomic Energy Authority)
    - RRE (Royal Radar Establishment, UK) and RADC (Rome Air Development Corporation, US).

Random vs Deterministic Failures



Traditional approach:

- **high** safety margin,
- safety factor (designed for 4-10 times normal stress, load) ← deterministic!
- result in overdesign, high costs, expensive complex systems !!

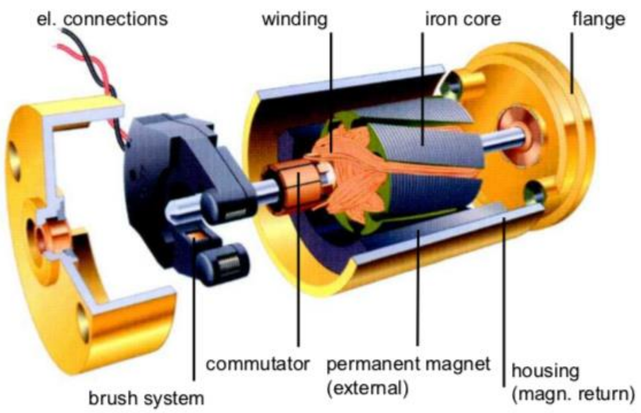
Classic way :

- system , component failures random, probabilistic occurrences.
  - In theory, exact physics can be known, internal failures can be predicted.
  - In reality, deterministic approach not feasible. WHY??
    - limited data, not exact model knowledge, exact physics not known.
    - physics of failures, faults not known exact.
    - human errors, environmental factors, “Acts of God” (flood, earthquake) can not be modelled.

But, we have data !!

- Probabilistic approach :
  - Use data to construct probabilistic reasoning,
  - inference from previous occurrences.
  - Estimate failure parameters from data, probabilistic models!!

Random vs Deterministic Failures



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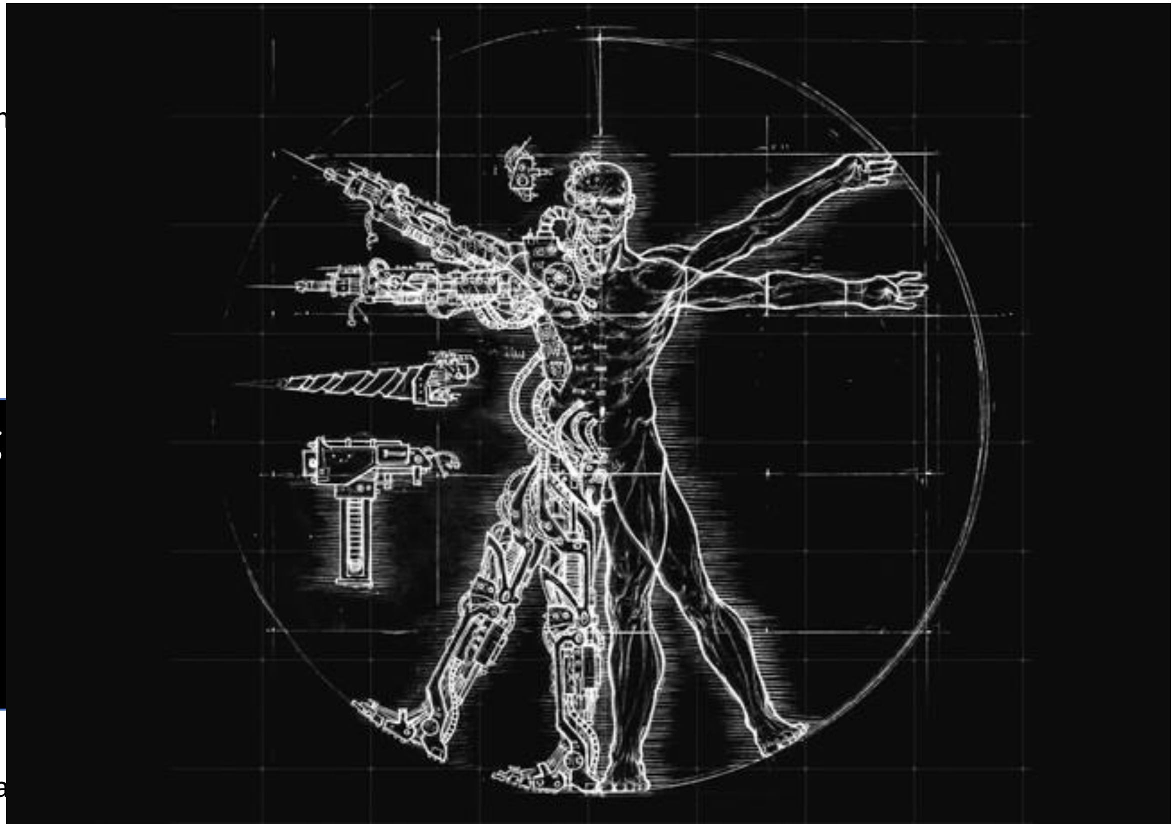
Things are changing with
Machine Learning and Artificial intelligence!

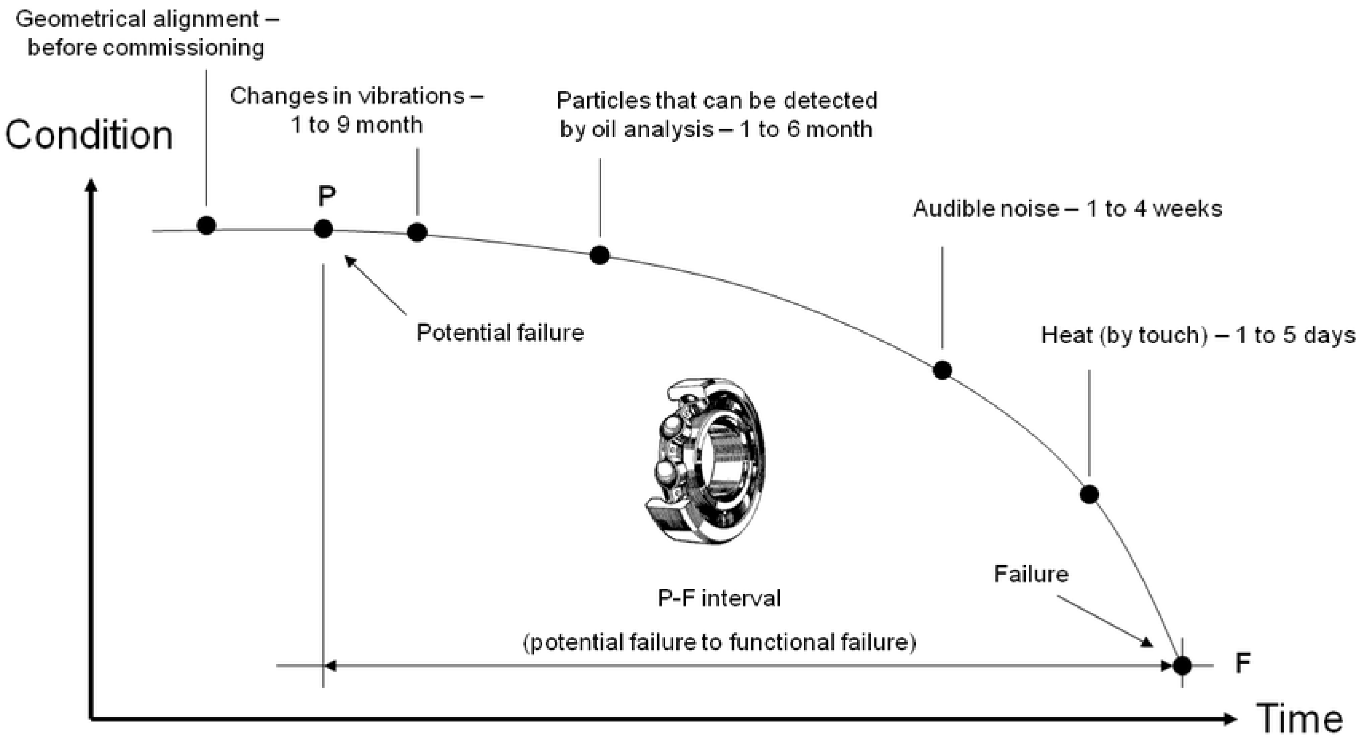


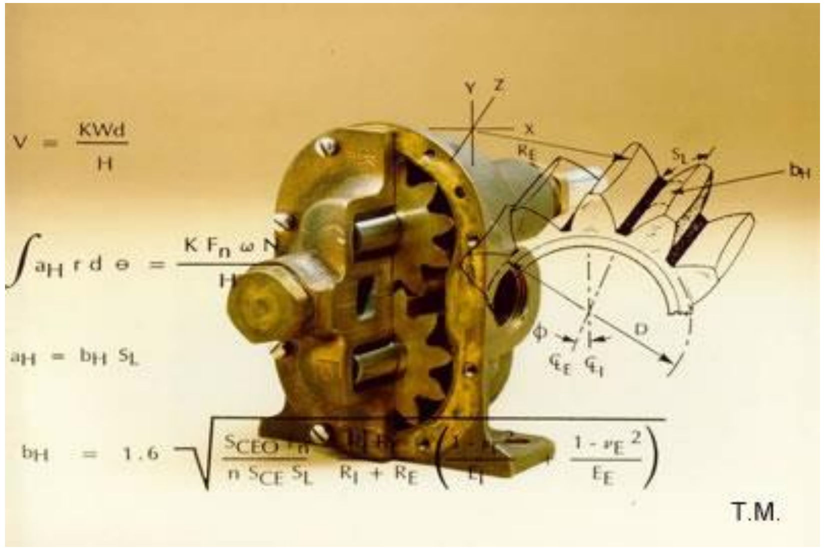
Literature in Reliability

- *IEEE Transaction on reliability*
- *Proceedings of Annual reliability and Maintainability Symposium*
- *Technometrics*
- *Applied Statistics*
- *Operations Research*
- *Reliability Review*
- *Reliability Engineering*
- *International Journal of reliability quality and safety engineering*

Reliability Application Areas

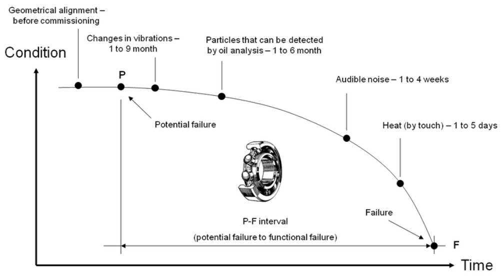
- **Mechanical reliability**
- **Software reliability**
- **Human reliability**
- **Reliability optimization**
- **Reliability growth**
- **Structural reliability**
- **Power system reliability**
- **Life cycle costing**
- **Maintainability**

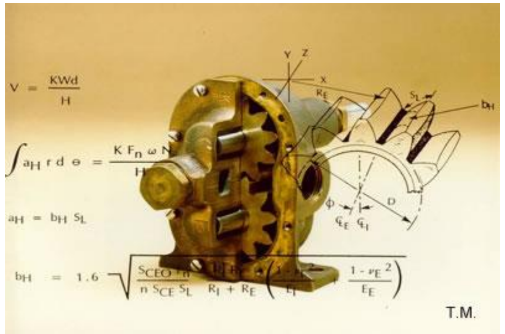


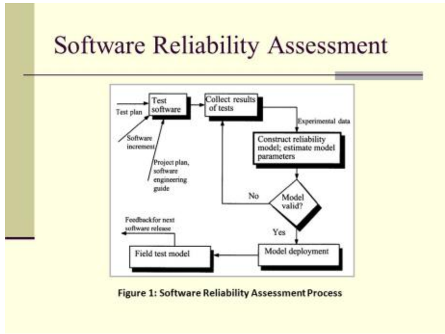


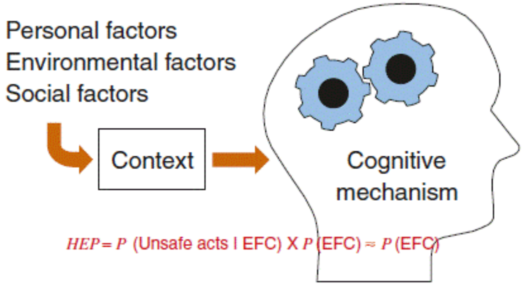
Reliability Application Areas

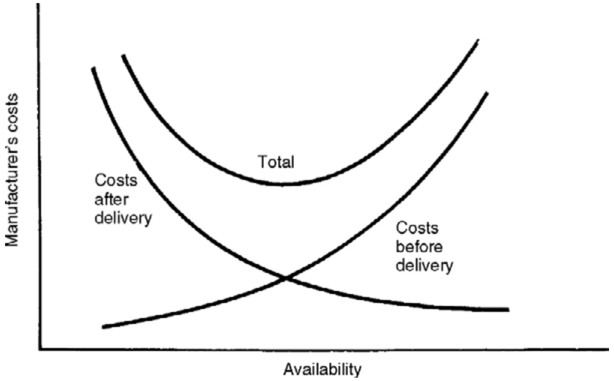
- Mechanical reliability
- Software reliability
- Human reliability
- Reliability optimization
- Reliability growth
- Structural reliability
- Power system reliability
- Life cycle costing
- Maintainability

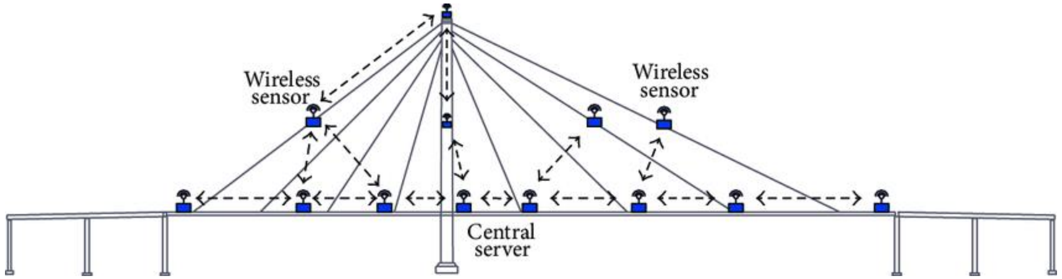












Basic Terms and Definitions

- **Reliability:** probability that an item will carry out its assigned mission satisfactorily for the stated time period when used under the specified conditions.
- **Failure:** This is the inability of an item to function.
- **Downtime:** This is the time period during which the item is not in a condition to carry out its stated mission
- **Maintainability:** This is the probability that a failed item will be repaired to its satisfactory working state.
- **Availability:** This is the probability that an item is available for application or use when needed.
- **Redundancy:** This is the existence of more than one means for accomplishing a defined function.
- **Mean time to failure , Mean time between failure, …..**

Achieving Reliability and Safety Integrity (High level view)

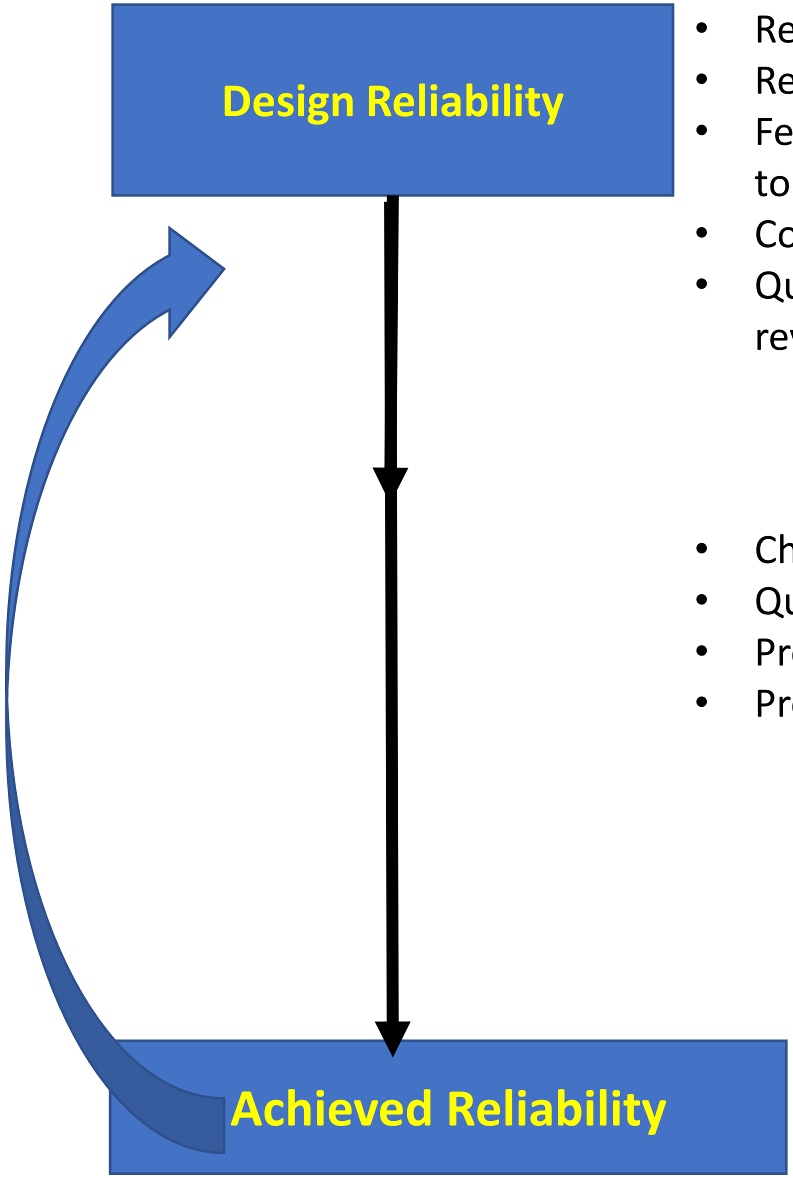
Failure is rarely due to one component of system,

failure may be due to:

- software elements
- human factors or operating documentation
- environmental factors
- ambiguity in the specification
- timing constraints within the design.

Reliability and safety are 'built-in' features of a design.

Maintainability, availability : depend upon failure rate and repair/down time.



Design

- Reduction in complexity
- Redundancy
- Feedback of failure information to increase reliability
- Component selection
- Qualification testing, design review

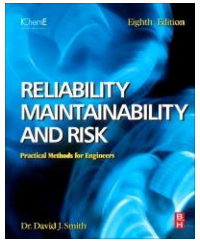
Manufacture

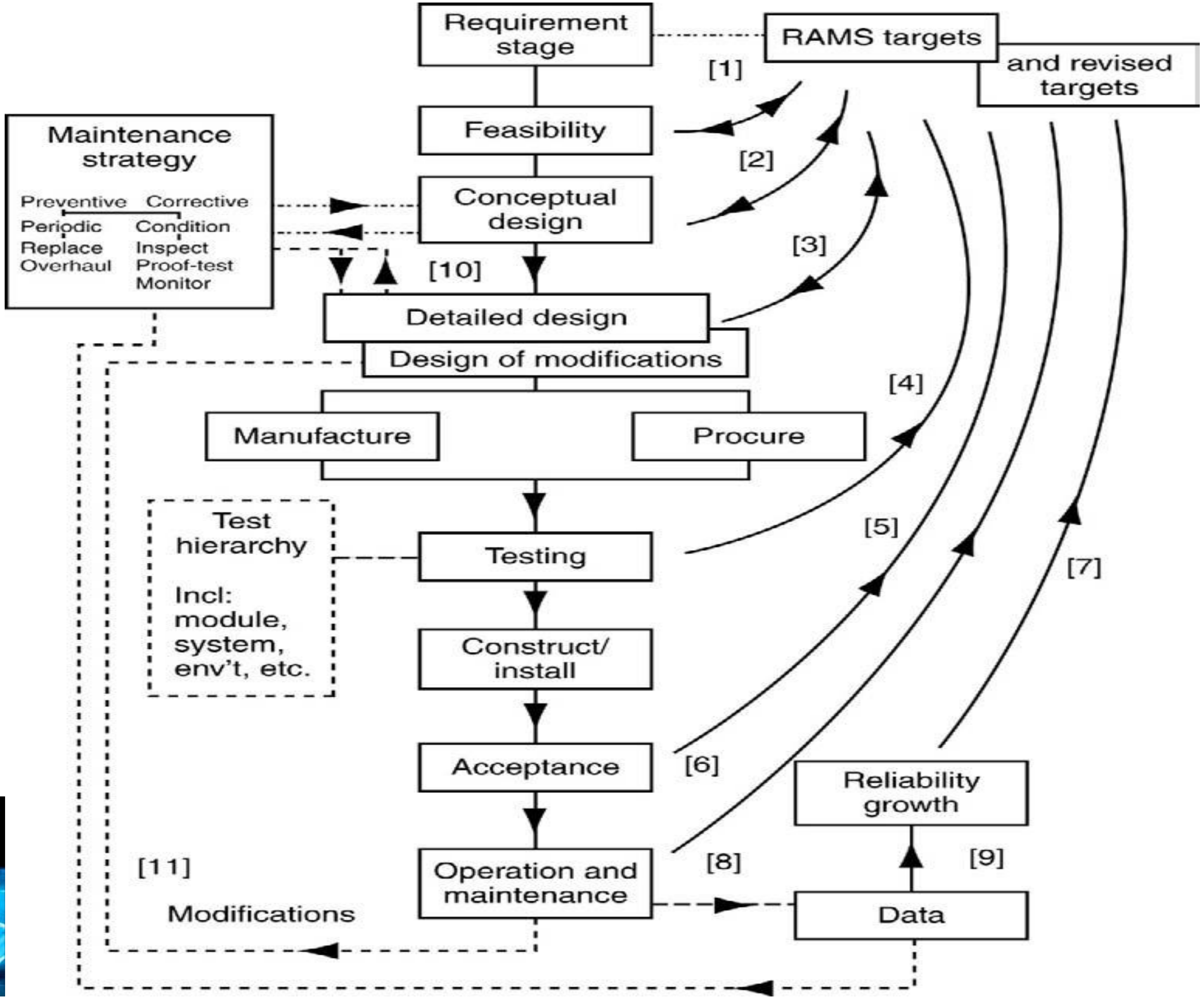
- Change control
- Quality assurance
- Production testing
- Process instructions

Field

- Failure feedback
- Replacement strategy
- Preventive maintenance
- User Interaction

RAMS Cycle





Smith, D. J. (2017). *Reliability, maintainability and risk: practical methods for engineers*. Butterworth-Heinemann.

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Sources of Failure Data

Organisations:

- **Reliability Analysis Center (RAC) :** Nonelectronic Parts Reliability Data (NPRD) reports by US Airforce.
- **Defense Technical Information Center :** Reliability data for defense equipment.
- **Parts Reliability Information Center (PRINCE):** Reliability of systems related to space
- **Institute of Electrical and Electronics Engineers (IEEE) :** failure data concerning various electrical related items.

Data Banks:

- **Nuclear Plant Reliability Data System (NPRDS):**Failure data on equipment used in nuclear power plants.
- **Equipment Reliability Information System (ERIS):** failure data on equipment used in electric power generation.
- **SYREL: Reliability Data Bank:** failure data on equipment used in power generation (UK).
- **OREDA (Offshore Reliability Data) - version 4 (2002)** : recueil européen concernant les matériels des compagnies pétrolières.
- **IEEE Standard 500 - 1984 (États-Unis) - Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear Power Generating Stations**

Guide : **Fides (reliability)**

- reliability calculation for ***electronic components and systems***.
- Fides is a DGA (French armament industry supervision agency) study conducted by a European consortium :

Airbus France – Eurocopter – GIAT Industries – MBDA Missile systems – THALES Airborne

Systems – THALES Avionics – THALES Research & Technology – THALES Underwater Systems

TABLE A.1

Standardized normal probabilities: $\Phi(z) = \int_{-\infty}^{z} (1/\sqrt{2\pi}) e^{-y^2/2}\, dy$

z	$\Phi(z)$	$1-\Phi(z)$	z	$\Phi(z)$	$1-\Phi(z)$	z	$\Phi(z)$	$1-\Phi(z)$
−4.00000	0.00003	0.99997	−3.51000	0.00022	0.99978	−3.02000	0.00126	0.99874
−3.99000	0.00003	0.99997	−3.50000	0.00023	0.99977	−3.01000	0.00131	0.99869
−3.98000	0.00003	0.99997	−3.49000	0.00024	0.99976	−3.00000	0.00135	0.99865
−3.97000	0.00004	0.99996	−3.48000	0.00025	0.99975	−2.99000	0.00139	0.99861
−3.96000	0.00004	0.99996	−3.47000	0.00026	0.99974	−2.98000	0.00144	0.99856
−3.95000	0.00004	0.99996	−3.46000	0.00027	0.99973	−2.97000	0.00149	0.99851
−3.94000	0.00004	0.99996	−3.45000	0.00028	0.99972	−2.96000	0.00154	0.99846
−3.93000	0.00004	0.99996	−3.44000	0.00029	0.99971	−2.95000	0.00159	0.99841
−3.92000	0.00004	0.99996	−3.43000	0.00030	0.99970	−2.94000	0.00164	0.99836
−3.91000	0.00005	0.99995	−3.42000	0.00031	0.99969	−2.93000	0.00169	0.99831
−3.90000	0.00005	0.99995	−3.41000	0.00032	0.99968	−2.92000	0.00175	0.99825
−3.89000	0.00005	0.99995	−3.40000	0.00034	0.99966	−2.91000	0.00181	0.99819
−3.88000	0.00005	0.99995	−3.39000	0.00035	0.99965	−2.90000	0.00187	0.99813
−3.87000	0.00005	0.99995	−3.38000	0.00036	0.99964	−2.89000	0.00193	0.99807
−3.86000	0.00006	0.99994	−3.37000	0.00038	0.99962	−2.88000	0.00199	0.99801
−3.85000	0.00006	0.99994	−3.36000	0.00039	0.99961	−2.87000	0.00205	0.99795
−3.84000	0.00006	0.99994	−3.35000	0.00040	0.99960	−2.86000	0.00212	0.99788
−3.83000	0.00006	0.99994	−3.34000	0.00042	0.99958	−2.85000	0.00219	0.99781
−3.82000	0.00007	0.99993	−3.33000	0.00043	0.99957	−2.84000	0.00226	0.99774
−3.81000	0.00007	0.99993	−3.32000	0.00045	0.99955	−2.83000	0.00233	0.99767
−3.80000	0.00007	0.99993	−3.31000	0.00047	0.99953	−2.82000	0.00240	0.99760
−3.79000	0.00008	0.99992	−3.30000	0.00048	0.99952	−2.81000	0.00248	0.99752
−3.78000	0.00008	0.99992	−3.29000	0.00050	0.99950	−2.80000	0.00255	0.99745
−3.77000	0.00008	0.99992	−3.28000	0.00052	0.99948	−2.79000	0.00264	0.99736
−3.76000	0.00008	0.99992	−3.27000	0.00054	0.99946	−2.78000	0.00272	0.99728
−3.75000	0.00009	0.99991	−3.26000	0.00056	0.99944	−2.77000	0.00280	0.99720
−3.74000	0.00009	0.99991	−3.25000	0.00058	0.99942	−2.76000	0.00289	0.99711
−3.73000	0.00009	0.99991	−3.24000	0.00060	0.99940	−2.75000	0.00298	0.99702
−3.72000	0.00010	0.99990	−3.23000	0.00062	0.99938	−2.74000	0.00307	0.99693
−3.71000	0.00010	0.99990	−3.22000	0.00064	0.99936	−2.73000	0.00317	0.99683
−3.70000	0.00011	0.99989	−3.21000	0.00066	0.99934	−2.72000	0.00326	0.99674
−3.69000	0.00011	0.99989	−3.20000	0.00069	0.99931	−2.71000	0.00336	0.99664
−3.68000	0.00012	0.99988	−3.19000	0.00071	0.99929	−2.70000	0.00347	0.99653
−3.67000	0.00012	0.99988	−3.18000	0.00074	0.99926	−2.69000	0.00357	0.99643
−3.66000	0.00013	0.99987	−3.17000	0.00076	0.99924	−2.68000	0.00368	0.99632
−3.65000	0.00013	0.99987	−3.16000	0.00079	0.99921	−2.67000	0.00379	0.99621
−3.64000	0.00014	0.99986	−3.15000	0.00082	0.99918	−2.66000	0.00391	0.99609
−3.63000	0.00014	0.99986	−3.14000	0.00084	0.99916	−2.65000	0.00402	0.99598
−3.62000	0.00015	0.99985	−3.13000	0.00087	0.99913	−2.64000	0.00415	0.99585
−3.61000	0.00015	0.99985	−3.12000	0.00090	0.99910	−2.63000	0.00427	0.99573
−3.60000	0.00016	0.99984	−3.11000	0.00094	0.99906	−2.62000	0.00440	0.99560
−3.59000	0.00016	0.99984	−3.10000	0.00097	0.99903	−2.61000	0.00453	0.99547
−3.58000	0.00017	0.99983	−3.09000	0.00100	0.99900	−2.60000	0.00466	0.99534
−3.57000	0.00018	0.99982	−3.08000	0.00103	0.99897	−2.59000	0.00480	0.99520
−3.56000	0.00019	0.99981	−3.07000	0.00107	0.99893	−2.58000	0.00494	0.99506
−3.55000	0.00019	0.99981	−3.06000	0.00111	0.99889	−2.57000	0.00508	0.99492
−3.54000	0.00020	0.99980	−3.05000	0.00114	0.99886	−2.56000	0.00523	0.99477
−3.53000	0.00021	0.99979	−3.04000	0.00118	0.99882	−2.55000	0.00539	0.99461
−3.52000	0.00022	0.99978	−3.03000	0.00122	0.99878	−2.54000	0.00554	0.99446

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−2.53000	0.00570	0.99430	−2.03000	0.02118	0.97882	−1.53000	0.06301	0.93699
−2.52000	0.00587	0.99413	−2.02000	0.02169	0.97831	−1.52000	0.06426	0.93574
−2.51000	0.00604	0.99396	−2.01000	0.02222	0.97778	−1.51000	0.06552	0.93448
−2.50000	0.00621	0.99379	−2.00000	0.02275	0.97725	−1.50000	0.06681	0.93319
−2.49000	0.00639	0.99361	−1.99000	0.02330	0.97670	−1.49000	0.06811	0.93189
−2.48000	0.00657	0.99343	−1.98000	0.02385	0.97615	−1.48000	0.06944	0.93056
−2.47000	0.00676	0.99324	−1.97000	0.02442	0.97558	−1.47000	0.07078	0.92922
−2.46000	0.00695	0.99305	−1.96000	0.02500	0.97500	−1.46000	0.07214	0.92786
−2.45000	0.00714	0.99286	−1.95000	0.02559	0.97441	−1.45000	0.07353	0.92647
−2.44000	0.00734	0.99266	−1.94000	0.02619	0.97381	−1.44000	0.07493	0.92507
−2.43000	0.00755	0.99245	−1.93000	0.02680	0.97320	−1.43000	0.07636	0.92364
−2.42000	0.00776	0.99224	−1.92000	0.02743	0.97257	−1.42000	0.07780	0.92220
−2.41000	0.00798	0.99202	−1.91000	0.02807	0.97193	−1.41000	0.07927	0.92073
−2.40000	0.00820	0.99180	−1.90000	0.02872	0.97128	−1.40000	0.08076	0.91924
−2.39000	0.00842	0.99158	−1.89000	0.02938	0.97062	−1.39000	0.08226	0.91774
−2.38000	0.00866	0.99134	−1.88000	0.03005	0.96995	−1.38000	0.08379	0.91621
−2.37000	0.00889	0.99111	−1.87000	0.03074	0.96926	−1.37000	0.08534	0.91466
−2.36000	0.00914	0.99086	−1.86000	0.03144	0.96856	−1.36000	0.08691	0.91309
−2.35000	0.00939	0.99061	−1.85000	0.03216	0.96784	−1.35000	0.08851	0.91149
−2.34000	0.00964	0.99036	−1.84000	0.03288	0.96712	−1.34000	0.09012	0.90988
−2.33000	0.00990	0.99010	−1.83000	0.03362	0.96638	−1.33000	0.09176	0.90824
−2.32000	0.01017	0.98983	−1.82000	0.03438	0.96562	−1.32000	0.09342	0.90658
−2.31000	0.01044	0.98956	−1.81000	0.03515	0.96485	−1.31000	0.09510	0.90490
−2.30000	0.01072	0.98928	−1.80000	0.03593	0.96407	−1.30000	0.09680	0.90320
−2.29000	0.01101	0.98899	−1.79000	0.03673	0.96327	−1.29000	0.09853	0.90147
−2.28000	0.01130	0.98870	−1.78000	0.03754	0.96246	−1.28000	0.10027	0.89973
−2.27000	0.01160	0.98840	−1.77000	0.03836	0.96164	−1.27000	0.10204	0.89796
−2.26000	0.01191	0.98809	−1.76000	0.03920	0.96080	−1.26000	0.10383	0.89617
−2.25000	0.01222	0.98778	−1.75000	0.04006	0.95994	−1.25000	0.10565	0.89435
−2.24000	0.01255	0.98745	−1.74000	0.04093	0.95907	−1.24000	0.10749	0.89251
−2.23000	0.01287	0.98713	−1.73000	0.04182	0.95818	−1.23000	0.10935	0.89065
−2.22000	0.01321	0.98679	−1.72000	0.04272	0.95728	−1.22000	0.11123	0.88877
−2.21000	0.01355	0.98645	−1.71000	0.04363	0.95637	−1.21000	0.11314	0.88686
−2.20000	0.01390	0.98610	−1.70000	0.04457	0.95543	−1.20000	0.11507	0.88493
−2.19000	0.01426	0.98574	−1.69000	0.04551	0.95449	−1.19000	0.11702	0.88298
−2.18000	0.01463	0.98537	−1.68000	0.04648	0.95352	−1.18000	0.11900	0.88100
−2.17000	0.01500	0.98500	−1.67000	0.04746	0.95254	−1.17000	0.12100	0.87900
−2.16000	0.01539	0.98461	−1.66000	0.04846	0.95154	−1.16000	0.12302	0.87698
−2.15000	0.01578	0.98422	−1.65000	0.04947	0.95053	−1.15000	0.12507	0.87493
−2.14000	0.01618	0.98382	−1.64000	0.05050	0.94950	−1.14000	0.12714	0.87286
−2.13000	0.01659	0.98341	−1.63000	0.05155	0.94845	−1.13000	0.12924	0.87076
−2.12000	0.01700	0.98300	−1.62000	0.05262	0.94738	−1.12000	0.13136	0.86864
−2.11000	0.01743	0.98257	−1.61000	0.05370	0.94630	−1.11000	0.13350	0.86650
−2.10000	0.01786	0.98214	−1.60000	0.05480	0.94520	−1.10000	0.13567	0.86433
−2.09000	0.01831	0.98169	−1.59000	0.05592	0.94408	−1.09000	0.13786	0.86214
−2.08000	0.01876	0.98124	−1.58000	0.05705	0.94295	−1.08000	0.14007	0.85993
−2.07000	0.01923	0.98077	−1.57000	0.05821	0.94179	−1.07000	0.14231	0.85769
−2.06000	0.01970	0.98030	−1.56000	0.05938	0.94062	−1.06000	0.14457	0.85543
−2.05000	0.02018	0.97982	−1.55000	0.06057	0.93943	−1.05000	0.14686	0.85314
−2.04000	0.02067	0.97933	−1.54000	0.06178	0.93822	−1.04000	0.14917	0.85083

Annex : Student *t* distribution Chart

TABLE A.2
Critical *t* values with ν degrees of freedom

ν	α = 0.100	0.050	0.025	0.010	0.005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.695	9.925
3	1.639	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
∞	1.282	1.645	1.960	2.326	2.576