

# 제품혁신을 위한 신뢰성 기술 개발 동향

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## 목 차

1. 신뢰성 지식기반 정보
2. 신뢰성 경영시스템 구축방향
3. 신뢰성 인증 시스템(IEC61508)
4. QR 개발동향

## 1. 신뢰성 지식기반 정보

### 1) 신뢰성 교육/연구기관

- (1) Us Air Force Institute of Technology  
Dayton, Ohio 45433 USA
- (2) Us Naval Post-Graduate School  
Monterey, California USA
- (3) Red River
  - ▶ A joint effort between:
    - US Army Development & Readiness Command, Intern Training Center, Red River Army Depot, Texarkana
    - Texas A&M University, College Station
- (4) US Army Management Engineering Training Activity  
AMETA, Rock Island, Illinois
- (5) US Army Intern Training Program
- (6) US Navy Intern Program
  - ▶ Quality Control
  - ▶ Reliability Engineering
  - ▶ Maintainability Engineering
  - ▶ Testing
  - ▶ Configuration Management
  - ▶ Mechanical Stress Analysis
  - ▶ Electrical Stress Analysis
- (7) University of Arizona  
Aerospace and Mechanical Engineering Dept, Tucson, Arizona
  - ▶ Reliability Engineering Courses
    - Reliability Engineering
    - Reliability & life Testing
    - Maintainability engineering
    - Probabilistic Mechanical Design by Reliability
    - Design of Experiments
    - and other
  - ▶ A Professional Certificate Award program in Reliability & Quality Engineering
    - Engineering Statistics
    - Reliability Engineering
    - Reliability Testing
    - Maintainability Engineering
    - Quality Control
    - Experimental Design
    - Probabilistic Mechanical Design
- (8) University of Maryland  
UMd, College Park, Maryland
  - ▶ Students can specialize in:
    - Assessment(root-cause failure analysis, probabilistic risk assessment, common-cause failure)
    - Testing & Operation(operator manufacturing methods)
    - Component & Structures Reliability(microelectronics & materials)
    - Electronic Packaging Reliability

- Software Reliability
  - ▶ Reliability Engineering Program offer over 15 courses related to reliability engineering, including:
    - Reliability Engineering
    - Reliability Analysis
    - Collection/Analysis of Reliability Data
    - Methods in Reliability Modeling
    - Human Reliability Analysis
    - and others
- (9) Rutgers, The State University of New Jersey  
Piscataway, New Jersey
- (10) New Jersey Institute of Technology  
NJIT, Newark, New Jersey
- ▶ NJIT offers a Master's Degree in Assurance Sciences in the Industrial Engineering Department. It provides course in:
    - Engineering Reliability
    - Maintainability Engineering
    - Industrial Quality Control
    - Distribution Logistics
  - ▶ NJIT also provides a Certificate Program in Systems Reliability & Safety, including:
    - Environmental Risk Assessment
    - Engineering Reliability
    - Maintainability Engineering
    - Safety in Facility and Product Design
- (11) The University of Tennessee  
UT, Knoxville, Tennessee
- ▶ The Maintenance & Reliability Center (MRC) at the University of Tennessee is a new resource focusing on:
    - Education
    - Research & Development
    - Information
    - Application of Advanced Maintenance
    - Reliability Engineering
- (13) General
- ▶ Today, other universities in the USA teach a few courses in reliability engineering. These universities include:
    - Virginia Polytechnic Institute & State Univ. (4 courses)
    - University of South Florida (4 courses)
    - Wayne State University(3 courses)
    - Penn State University(3 courses)
    - Arizona State University(3 courses)

## 2) 신뢰성 텍스트자료

- ▶ Over 400 books have been published in reliability & maintainability engineering, and more are coming out ever year.

### 3) 신뢰성 세미나, 단기코스

- ▶ Prominent university efforts have been:
  - University of Arizona, Tucson
  - University of Maryland, College Park
  - University of California, Los Angeles
  - George Washington University, Washington DC.
- The University of Arizona offers 4 Institutes annually:
  - The Annual Reliability Testing Institute
  - The Annual Reliability Engineering and Management Institute
  - The Annual Applied Reliability Engineering and Product Assurance Institute for Engineers and Managers
  - Statistical Analysis of All Types of Data and Its Software (SAT SOFT)
- ▶ ASQ now sponsors professional & technical development courses on a wide range of quality topics, including:
  - Reliability Engineering
  - System Safety and Reliability Analysis
  - Failure Modes and Effects Analysis
  - Software Quality Engineering
- ▶ RAC currently has the following courses in both private (on-site) and open registration modes(courses can be tailored to suit individual user needs):
  - Design Reliability
  - Mechanical Reliability
  - Advanced Design Reliability(Robust Circuit Design)
  - Total Quality Management/Statistical Process Control
  - Accelerated Testing
  - System Software Reliability

### 4) 신뢰성 심포지움

- ▶ The first 'National Symposium on Quality Control and Reliability in Electronics'(1954), cosponsored by the:
  - Professional Group on Quality Control, IRE
  - Electronics Technical Committee, ASQC
- ▶ The first 'Reliability and Maintainability Conference(1962)  
It merged with the Annual Symposium on Reliability(1971)  
→ Annual Reliability and Maintainability Symposium
- ▶ A partial list of other current symposia is:
  - The Annual ISSAT Conference on Reliability and Quality in Design
  - The IEEE International Integrated Reliability Workshop(IRWS)
  - The IEEE International Reliability Physics Symposium
  - The International Symposium on Software Reliability Engineering, sponsored by IEEE Computer and Reliability Societies
  - The Annual Spring Reliability Symposium, Boston IEEE Reliability Chapter
  - The PSAM-IV International Conference on Probabilistic Safety Assessment and Management, New York City
  - The Annual Reliability, Maintainability, Supportability & Logistics Conference & Workshop (RMSL), sponsored by SAE G-11 Divison
  - The Maintenance and Reliability Conference, sponsored by The Maintenance and Reliability Center, The University of Tennessee

- The Machinery Reliability Conference and Exposition, sponsored by the RELIABILITY magazine.

#### 5) 신뢰성 출판물

- ▶ Conference Proceedings/Transactions
  - Proceedings and Tutorial-Notes of the Annual Reliability and Maintainability Symposium
  - Proceedings of the International Reliability Physics Symposium
  - Proceedings of the Annual Technical Meeting of the IEST
  - Reliability and Life Testing
- ▶ 13 Prominent Periodicals
  - IEEE Transactions on Reliability, IEEE
  - Reliability Engineering & System Safety
  - Quality and Reliability Engineering International
  - Microelectronics and Reliability
  - Technometrics
  - Quality Progress
  - Journal of Quality Technology, ASQ
  - Communications in Statistics: Theory and Methods
  - Journal of the American Statistical Association
  - Operations Research
  - Journal of Structural Engineering
  - Journal of Engineering Mechanics
  - International Journal of COMADEM
- ▶ Trade Magazines
  - Reliability magazine
  - Quality
  - Evaluation Engineering
  - Test Engineering and Management
  - Machine Design
  - Electronics Week
  - Environmental Quarterly
- ▶ Newsletters
  - IEEE Reliability Society Newsletter, IEEE
  - RAC Journal
  - The GIDEP Newsletter
  - Reliability Assessment
  - SRE Newsletter Lambda Notes
  - System Safety Society Chapter Newsletter

#### 6) 신뢰성 관련 기구

IEEE Reliability Society  
 Society of Reliability Engineers(SRE)  
 ASQ Reliability Division  
 ASQ Electronics Division  
 SAE Reliability, Maintainability, Supportability, and Logistics Division (G-11)  
 Society for Maintenance & Reliability Professionals (SMRP)  
 System Safety Society (SSS)  
 World Reliability/Quality Organization (WRO)

American Institute for Aeronautics and Astronautics (AIAA)  
Institute of Environmental Science & Technology (IEST)  
Institute of Industrial Engineers (IIE)  
Society of Logistics Engineers (SOLE)

#### 7) 신뢰성 관련 표준

- ▶ Reliability Standards & Handbooks
  - MIL-HDBK-189, Reliability Growth Management
  - MIL-HDBK-217F, Reliability Prediction of Electronic Equipment
  - MIL-HDBK-251, Reliability/Design Thermal Applications
  - MIL-HDBK-338, Electronic Reliability Design Handbook
  - MIL-HDBK-344, Environmental Stress Screening of Electronic Equipment
  - MIL-STD-690C, Failure Rate Sampling Plans and Procedures
  - MIL-HDBK-781, Reliability Test Methods, Plans and Environments for Engineering Development, Qualification and Production
  - MIL-STD-790F, Reliability Assurance Program for Electronic Parts Specifications
  - MIL-STD-810, Environmental Test Methods and Engineering Guidelines
  - MIL-STD-883, Test Method and Procedures for Microelectronics
  - MIL-HDBK-2155, Failure Reporting, Analysis and Corrective Action System (FRACAS)
  - MIL-HDBK-2164, Environmental Stress Screening Process for Electronic Equipment
- ▶ Maintainability Standards & Handbooks
  - MIL-HDBK-470A, Designing and Developing Maintainable Products and Systems
  - MIL-HDBK-472, Maintainability Prediction
  - MIL-HDBK-791, Maintainability Design Techniques
  - MIL-HDBK-2084, Maintainability of Avionics & Electronic Systems and Equipment
  - MIL-HDBK-2165, Testability Program for Electronic Systems and Equipment
- ▶ Other Standards on Quality Assurance and Reliability Engineering
  - ISO 9000 series
  - ISO 14000 series
  - IEC Publications issued by TC 56
    - IEC 60300, Dependability Management
    - IEC 60605, Equipment Reliability Testing,
    - IEC 60706, Guide on Maintainability of Equipment
    - IEC 60812, Analysis Techniques for System Reliability
    - IEC 61163, Reliability Stress Screening

#### 8) 신뢰성 관련 사이트

- ▶ The National Information Center for Reliability Engineering  
<http://www.enre.umd.edu/mainnojs.html>
- ▶ FAA Center for Aviation System Reliability  
<http://www.cnde.iastate.edu/faa.html>
- ▶ The Reliability Engineering Program at The University of Arizona homepage  
<http://www.u.arizona.edu/~dimitri>
- ▶ Harris Semiconductor Reliability Engineering Web site  
<http://rel.semi.harris.com>
- ▶ Reliability Analysis Center (RAC) Web site  
<http://rac.iitri.org>
- ▶ Reliability Sciences

- ▶ [http://www.cs.colorado.edu/homes/mcbryan/public\\_html](http://www.cs.colorado.edu/homes/mcbryan/public_html)
- ▶ Software Assurance Technology Center (SATC)  
<http://satc.gsfc.nasa.gov/homepage.html>
- ▶ IEEE Reliability Society homepage  
<http://ewh.ieee.org/soc/rs>
- ▶ Society of Reliability Engineers (SRE) homepage  
<http://www.sre.org>
- ▶ Institute of Environmental Science & Technology(IEST) homepage  
<http://www.iest.org/>
- ▶ Society for maintenance & Reliability Professionals(SMRP) homepage  
<http://www.smrp.org/>
- ▶ World Reliability/Quality Organization (WRO) homepage  
<http://www.world5000.com/wro>
- ▶ NASA : Its focus on safety, reliability, and quality assurance (SR&QA) resources  
<http://www-osma.lerc.nasa.gov/w3rel.htm>
- ▶ Commercial Reliability Web site  
<http://www.barringer1.com/links.htm>
- ▶ John Wiley InterScience  
<http://www.interscience.wiley.com>
- ▶ IEEE publication site  
(This site is known OPERA; Online Periodicals Research Area)  
<http://www.opera.ieee.org/>
- ▶ National Information Center for Reliability Engineering  
<http://www.enre.umd.edu/mainnojs.html>

#### 9) 신뢰성 영상자료

- ▶ The University of Arizona and the University of Maryland transmit reliability engineering courses directly to industry by their Instructional Television Systems.
- ▶ The University of Arizona's VIDEOCAMPUS, through its Distance Learning Division, has videotaped reliability engineering courses which include:
  - Applied Reliability Engineering in Action
  - Applied Burn-in Testing: Its Quantification and Optimization
  - Applied Environmental Stress Screening: Its Quantification, Optimization, and Management
  - Modern Engineering Design by Reliability and Mechanical Reliability Using the Stress/Strength Interference Approach
  - Applied Maintainability Engineering, Preventive Maintenance Scheduling, and Their Optimization
  - Applied Accelerated Reliability and Life Testing Concepts
  - Applied Bayesian Reliability and MTBF Testing
  - Mechanical Reliability and Probabilistic Design for Reliability
  - Reliability and Maintainability Engineering in Action
  - Reliability and Quality Analysis
  - Applied Reliability and MTBF Growth Testing Techniques and New Product Marketing Strategies
  - The Weibull Distribution and Its Reliability and Maintainability Engineering Applications
  - Reliability Engineering
  - Reliability Testing

- ▶ The IEEE Educational Activities Board and the IEEE Reliability Society co-produce tutorial videos on reliability engineering. The following videos are available:
  - Design Systems for Reliable Human Performance
  - Concurrent Engineering Perspectives: Concept to Success
  - Developing Reliable Software in the Shortest Cycle Time
- ▶ Other sources include but are not limited to:
  - AMCEE, Association for Media-Based Continuing Education for Engineers; 225 N. Avenue, NW; Atlanta, Georgia 30332 USA
  - Engineering Renewal and Growth; Engineering Research Center; Colorado State University; Fort Collins, Colorado 80523 USA
  - Juran Institute Inc; POBox 811 (11 River Rd); Wilton, Connecticut 06897-0811 USA
  - ASQ Quality Press; 611 E. Wisconsin Ave; Milwaukee, Wisconsin 5321-3005 USA

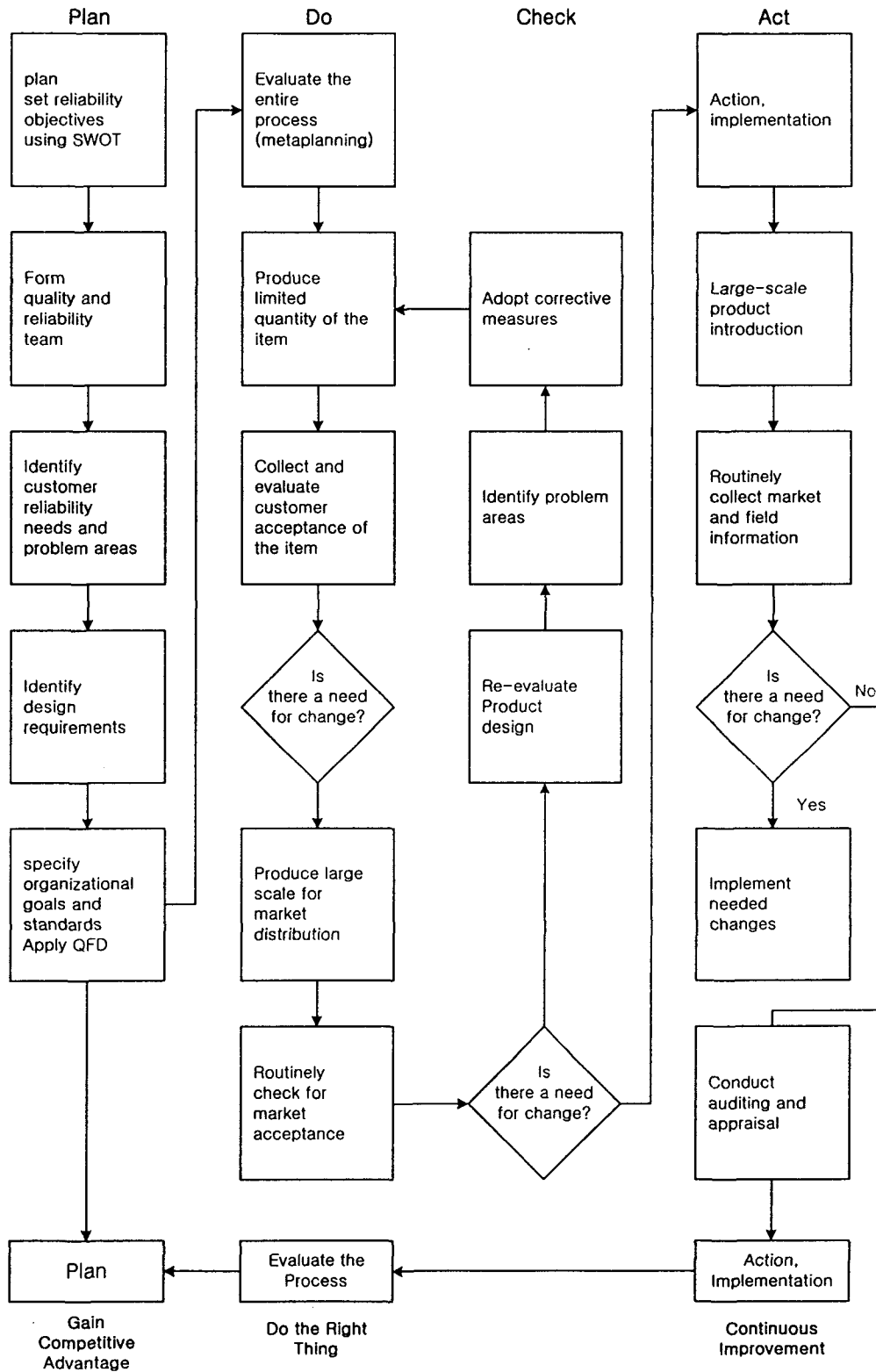
#### 10) 제언

- ▶ For industries to survive in the intense worldwide competition, they must learn how to conceive, design, manufacture, test, package, and deliver to the user, products that:
  - perform their unique designed-for function reliably
  - are easy to maintain or need no maintenance for their designed life,
  - are of high, impeccable quality
  - sold at globally competitive prices
- ▶ Strongly recommend that Colleges of Engineering require that all engineers have at least one course in:
  - Engineering probability & statistics
  - reliability engineering

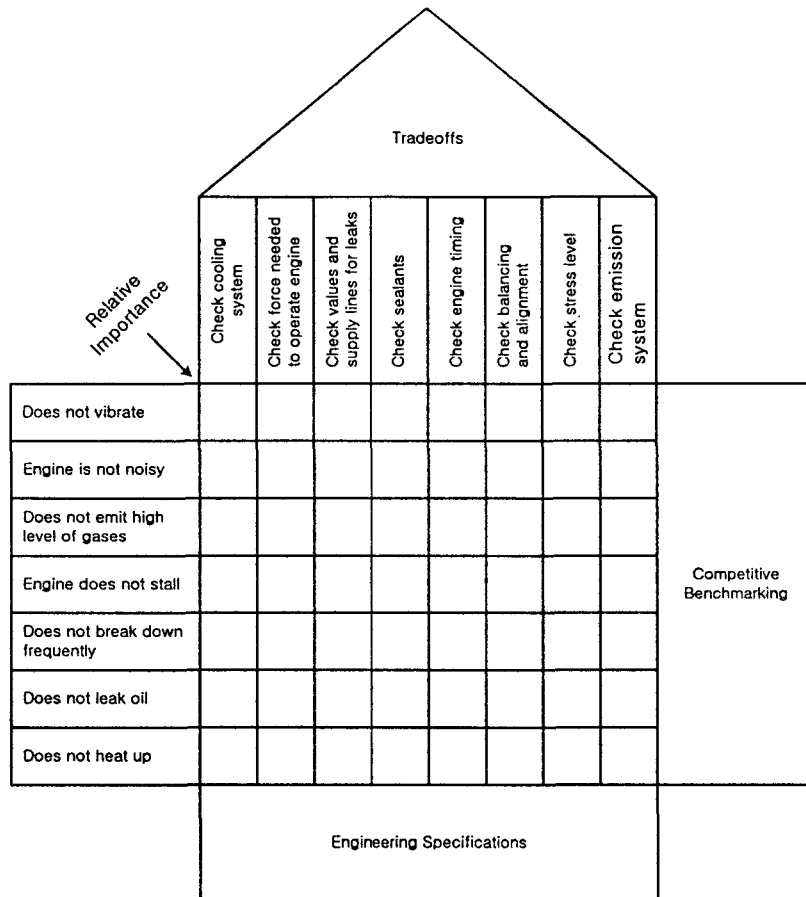


## 2. 신뢰성 경영시스템 구축방향

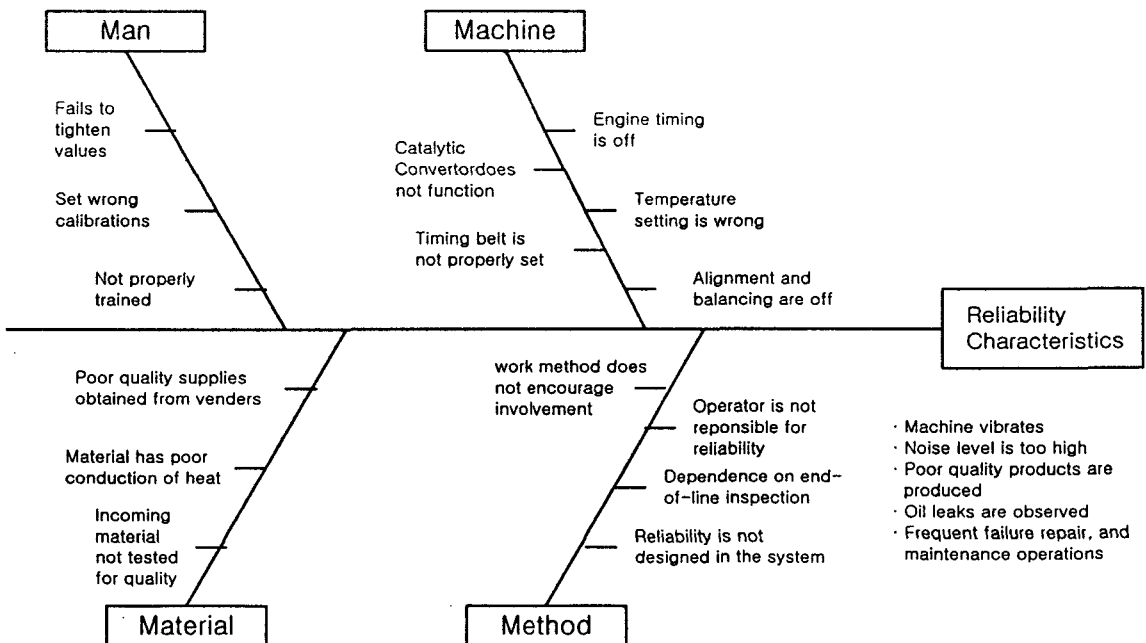
- 1) 품질/신뢰성 통합 모형  
 (1) 종합 신뢰성경영 절차



(2) 신뢰성 기능전개

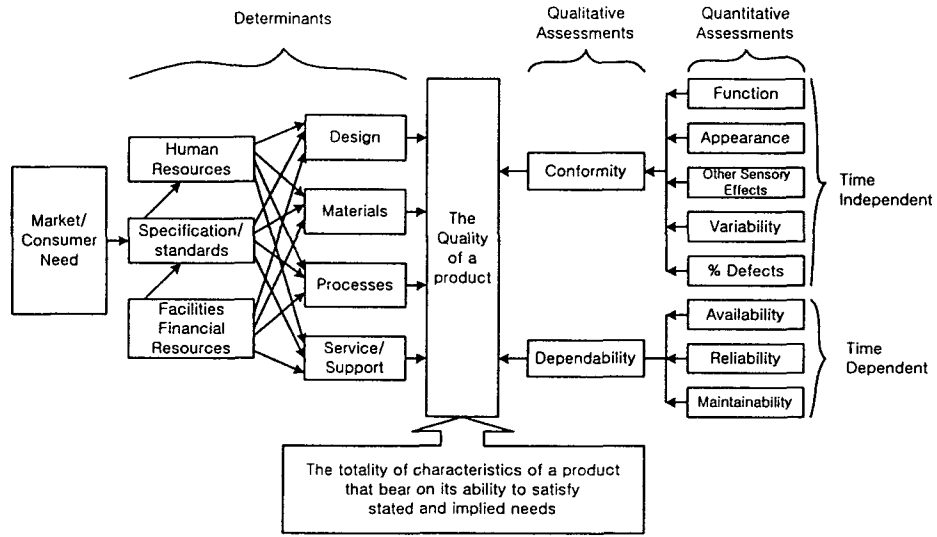


(3) 신뢰성 특성요인도

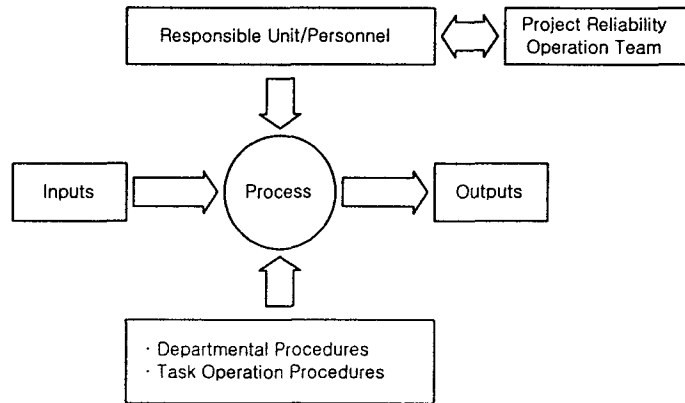


## 2) ISO 9000 기반 신뢰성 경영

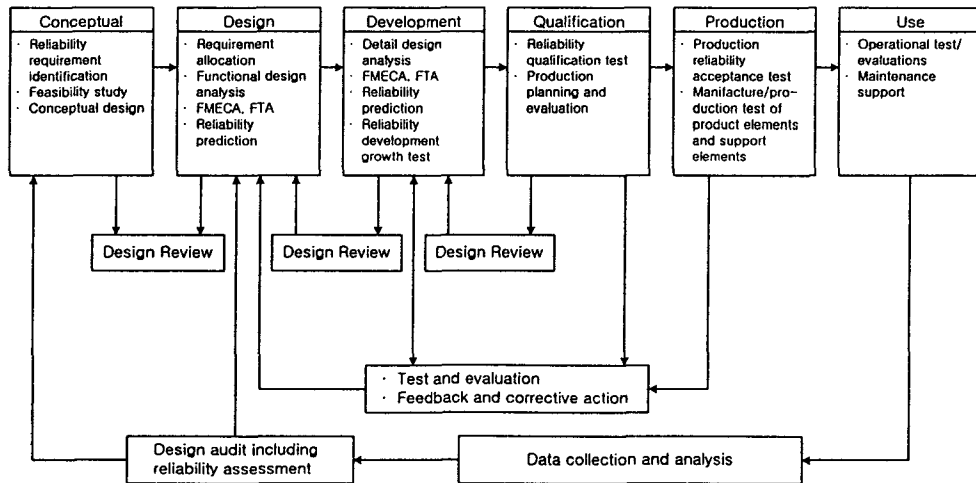
### (1) 제품 품질 평가



### (2) 개발과정 경영모델

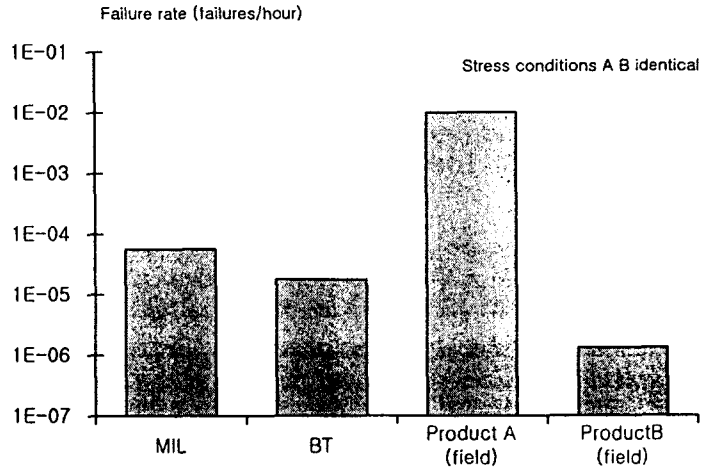


### (3) 제품 개발 프로세스

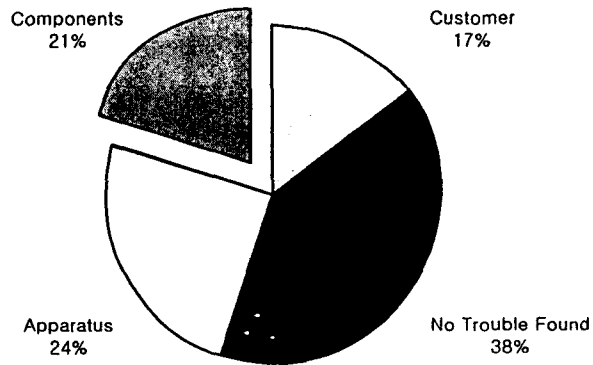


### 3. 신뢰성 인증 시스템(성숙도지표 MIR)

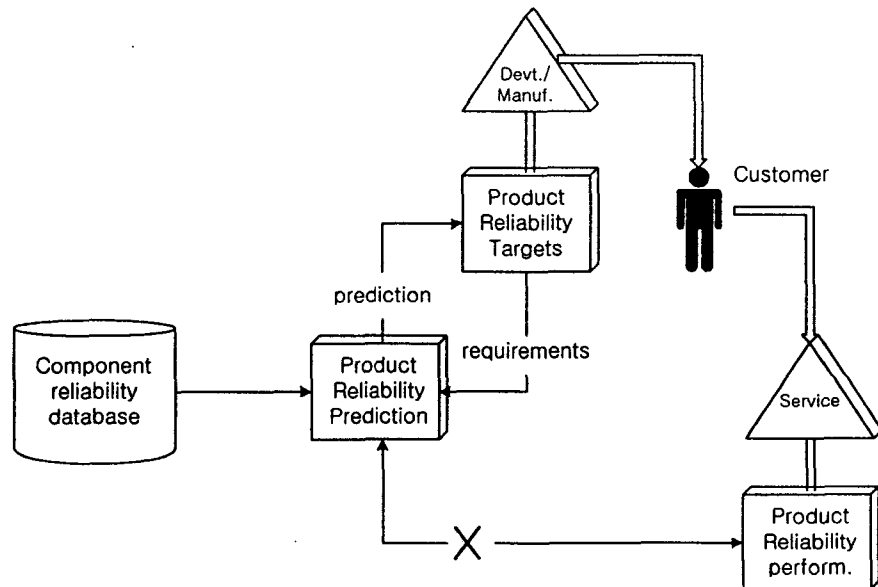
#### 1) 신뢰성 기준 예측자료의 문제



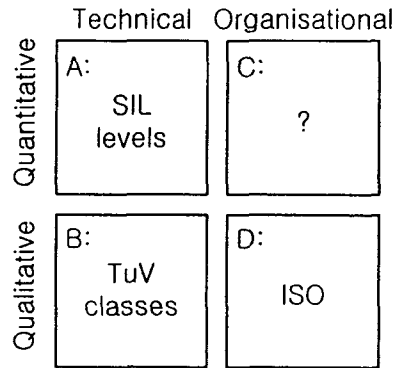
#### 2) 신뢰성 문제의 범주



#### 3) 신뢰성 예측/통제 사이클

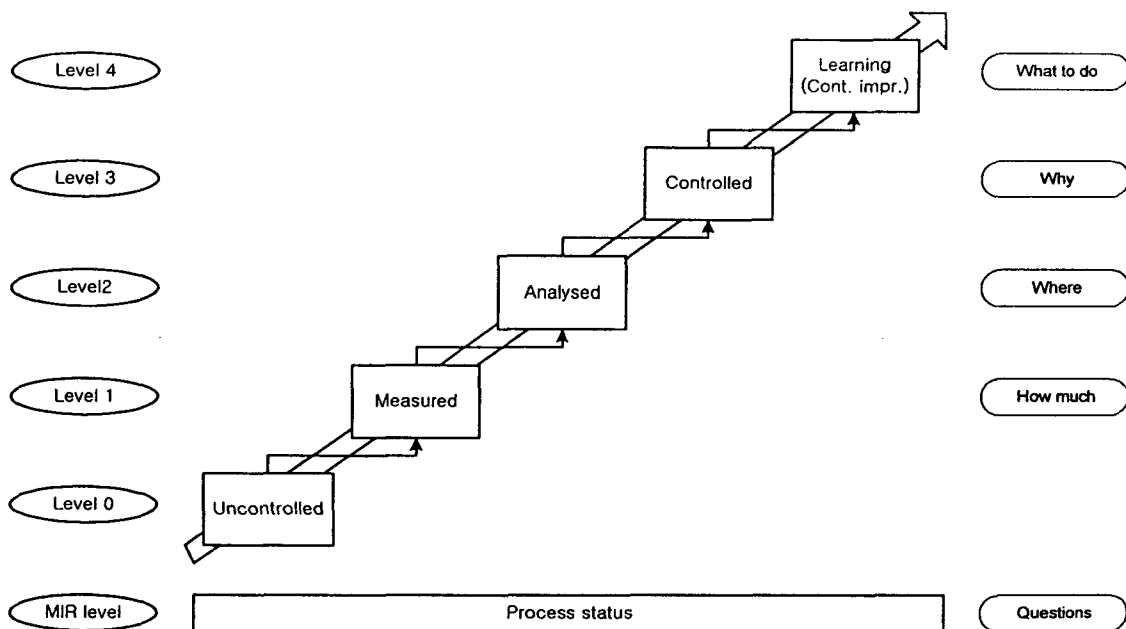


4) IEC 61508 4분역과 대응표준

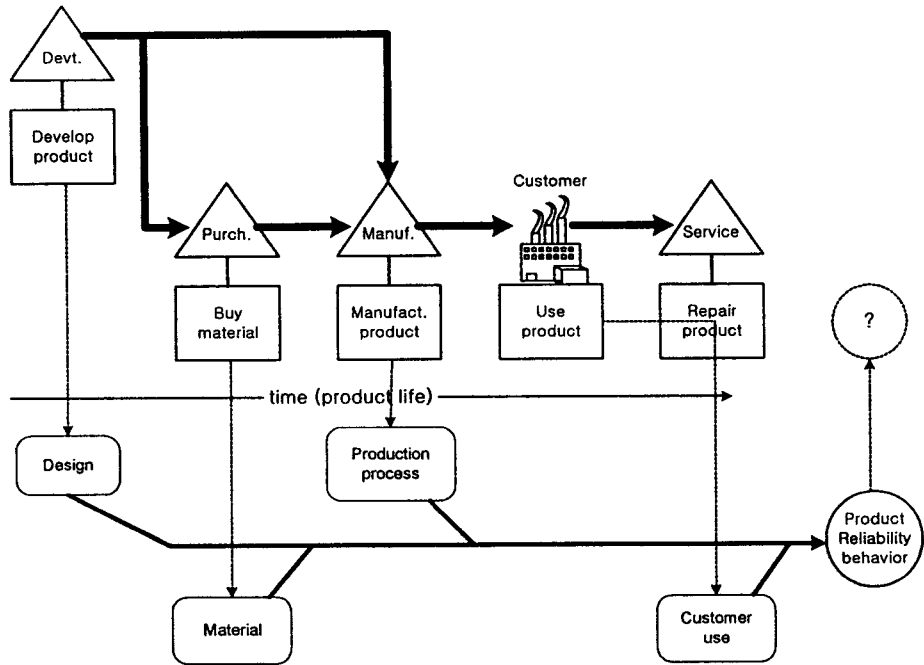


Methods and tools	Availability
A Methods for quantitative analysis of safety aspects on product level such as: Parts Count analysis, reliability block diagrams, fault trees and markov analysis.	Many methods and tools are available; different methods may lead to different results.
B Methods for qualitative analysis of safety aspects on product level such as TUV DIN 0801.	Yes
C Assessment of the maturity of the entire life cycle of a product	No standard method available yet
D Methods for assessment of the qualitative maintenance of related procedures and documentation such as ISO 9000.	Yes

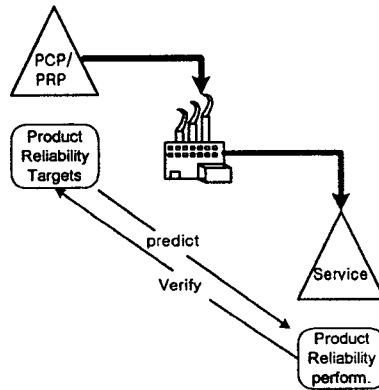
5) 신뢰성 성숙도 MIR



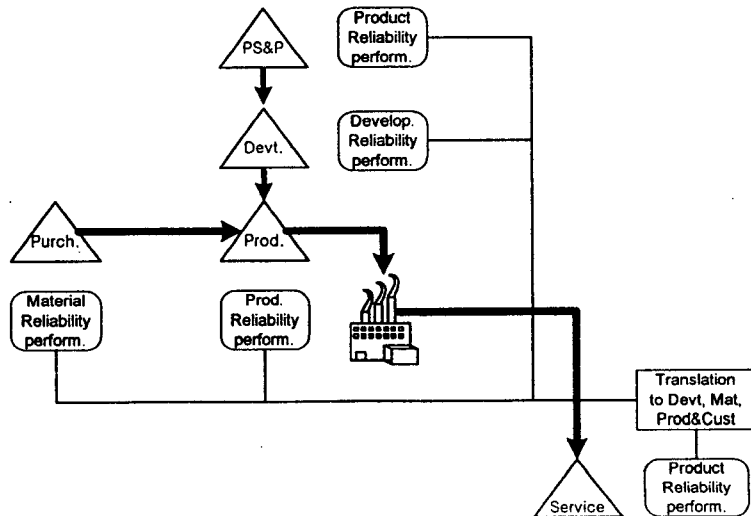
(1) MIR 0: zero or more predictions; no validation



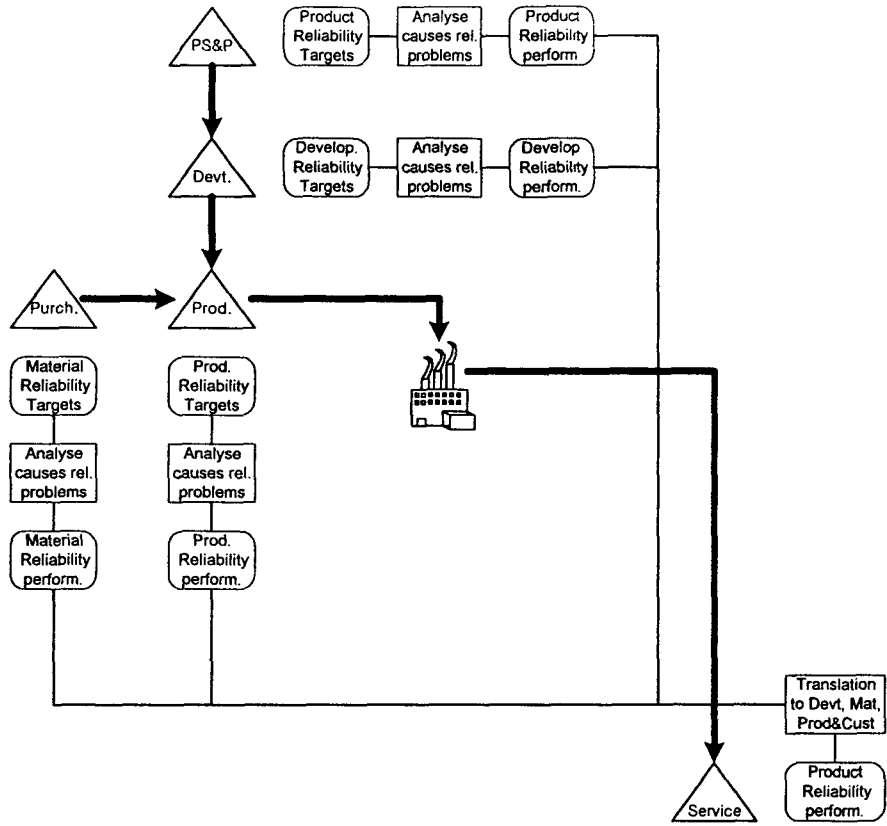
(2) MIR level 1.



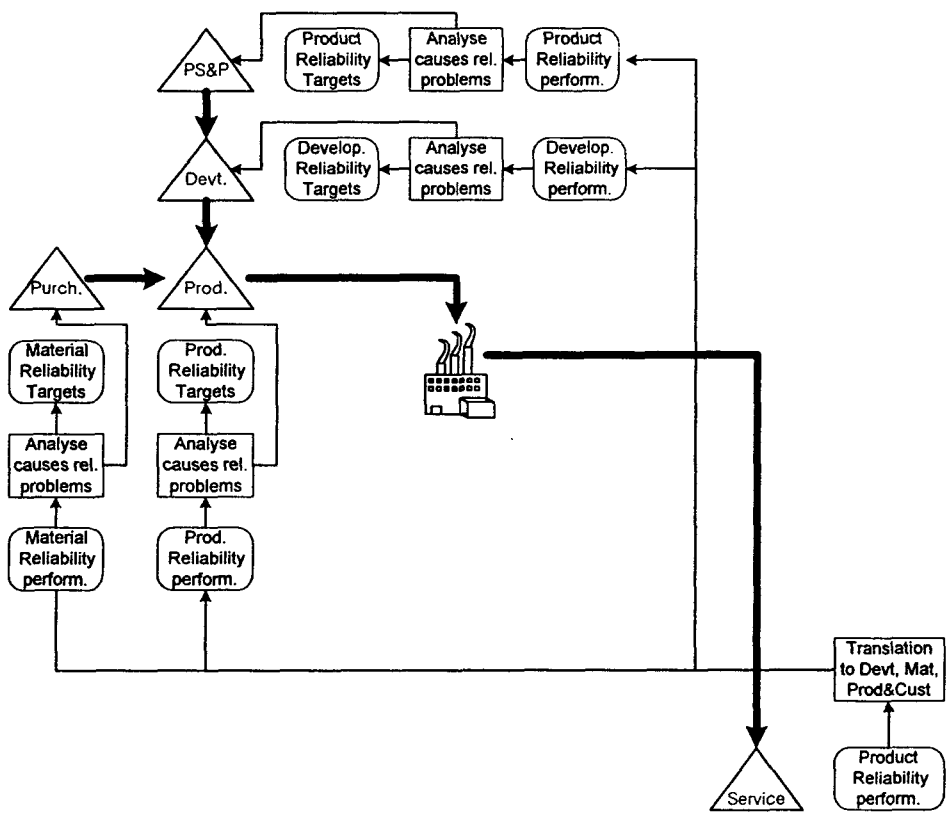
(3) MIR level 2



(4) MIR level 3; controlled.



(5) MIR level 4; continuous improvement.



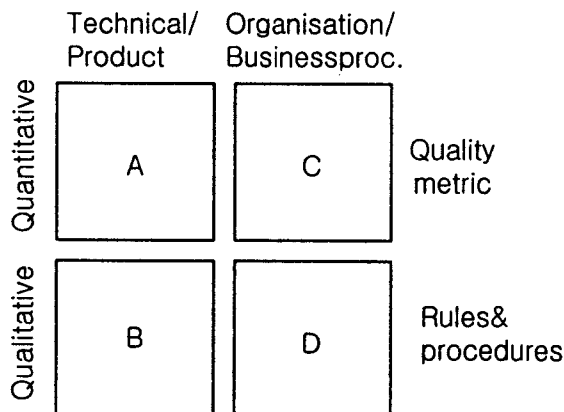
(6) IEC 61508 SIL 4 요구사항

IEC 61508 SIL 4 requirements	Requirement
1. Documents and procedures	Reliability and Safety related business process
2. Hardware analysis	Hardware design manual Design measures against CCF Design measures against systematic failures Review FMEA results Review fault injection tests Review failure data
3. Software quality	Review software quality manual Software structure Review software test program
4. Testing	Review functional tests

(7) 정보흐름과 MIR 수준

Information-flow/ database	Purpose	Input from	Output to	MIR level
A	Predict product reliability performance	MIL-HDBK-217	Sales dept	0
B	Development project records(eg. FMEA)	Development	-	0
C	Production quality records	Production	Production	3
D	Customer interviews	Customer	—(Management, sales)	0
E	Field service information	Service engineers	—(Management)	0
F	Module repair information	Repair engineers	-	0

(8) IEC 61508 4분역

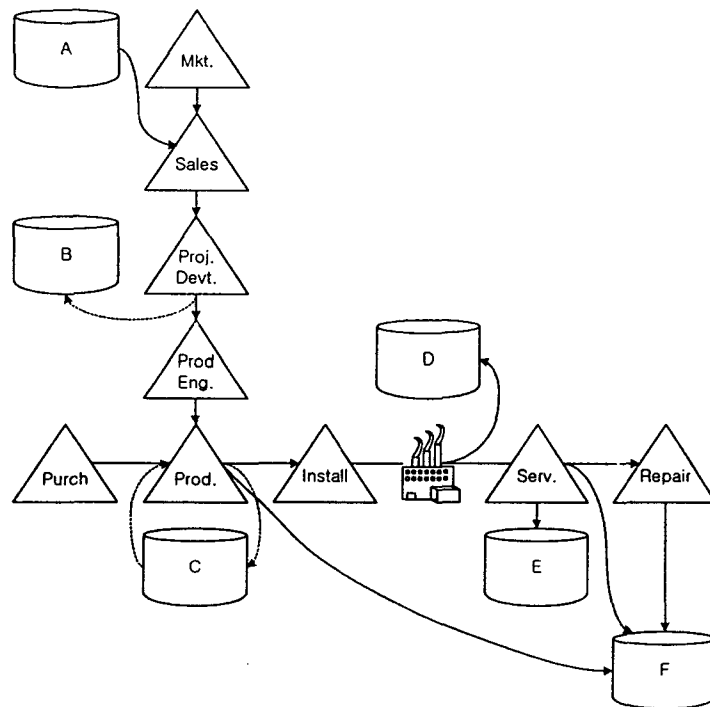




(9) IEC 61508 SIC 4 요구사항 및 MIR수준

IEC 61508 SIL 4 requirement	Requirement	Information available	Embedded in business process? (current MIR level)	Expl.	Required MIR level
1. Documents and procedures	Reliability and safety related business Process	Y	N(0)	I	1,(2,3,4)
	Reliability program plan or manual	Y	N(0)	I	1,(2,3,4)
2. Hardware analysis	Hardware design manual	Y	N(0)	B	3
	Design measures against common cause failures	Y	N(0)	B	3
	Design measures against systematic failures	Y	N(0)	I/B	3
	Review FMEA results	Y	N(0)	I/B	2
	Review Fault injection tests	Y	N(0)	I	3
	Review failure data	Y	Y, prod(3)/N, field(0)	I	1
3. Software quality assurance	Review software quality manual	Y	N(0)	B	3
	Software structure	Y	N(0)	B	1
	Review software test program	Y	N(0)	B	3
4. Testing	Review functional tests	Y	N(0)	B	3

(10) MIR 평가 결과



## 4. QR 개발동향

### 1) QR의 도입배경

- 가. 설비/시스템사용자의 신뢰성 주요업무;  
자료수집/분석 시스템의 구축, 자료의 경영활동에의 활용, 신뢰성기법의 개발
- 나. 신뢰성 정보 개발;  
LCC-최적화된 설계, 적합한 신뢰성의 설계, LCC-기초한 관련자의 문서, 제품규격
- 다. QR(정량적 신뢰성) 방법의 개발속성;  
(예측계산, 설계, 비용분석 측면에서)  
적합한 정확성, 실용적 가치성, 자료획득의 간편성, 해석의 간편성,  
사용자-공급자의 전이의 간편성, 통합의 간편성, 채택의 간편성

### 2) QR정보의 필요성

- 가. 제품구매자/사용자의 신뢰성업무부문  
(미정부계약시 신뢰성예측필수, 동시공학과와의 연계성)
  - (1) Optimization of system constitution, configuration, redundancy, and operating and maintenance procedures
  - (2) Specification of required reliability
  - (3) Comparative product and design evaluation at time of procurement
  - (4) Planning and sustaining maintenance and logistic resources
  - (5) Institution of optimum preventive maintenance procedures and frequencies
  - (6) Detection and correction of reliability and LCC problems in the operation of the equipments and systems under the user's control
  - (7) Implementation of guarantee and reliability incentive schemes
  - (8) Determination of optimum replacement or overhaul time of aging equipment
- 나. 사용자와 공급자의 역할
  - (1) 고객의 QR요구에 대응한 개발/설계자의 결정;  
설계전략, 개발 시험 프로그램 결정,  
용장성 요구 및 수준결정,  
LCC최소화, 신뢰성만족도, 안정성요구간의 조정
  - (2) 고객의 책임;  
(제한된 비용, 시간, 가용자원, 제반현실 여건 하에서)  
신뢰성요구사항의 적합성, 완비성, 일치성, 정확성, 타당성  
신뢰성 예측 기법기술,  
사용현장자료의 준비(MIL-STD-217),  
상관성 발견(공급자의 설계, 제조, 검사, 시험인자와 사용자의 사용현장자료간)
- 다. QR 기법에 대한 요구사항  
QR기법의 요구: 1994년 Annual R&M Symposium에서 신뢰성예측분야
  - (1) Simplicity of data acquisition, databank consolidation, data interpretation, user-producer transfer
  - (2) Simplicity of predictive calculations and design or cost analyses
  - (3) Indication of uncertainty range of any quoted test-obtained or field-obtained data and resulting calculations

### 3) QRE분야에서 현행 문제

- 가. 신뢰성 예측에서의 문제
  - (1) 전통적 방법의 부정확  
MIL-HDBK-217에서 MTBF(h)와 실제 시험MTBF,

SINGARS NDI(non-developmental item single-channel ground-air radio sets)

9개 다른 공급자로부터 구입비교 (표1),

사용현장자료와 예측자료의 비교 (표2),

사용현장 MTBF/예측된 MTBF

(2) MIL-HDBK-217의 큰오류

일정한 컴포넌트 고장률을 가정

컴포넌트 고장률 PiQ를 배분

설비의 설계/개발과정, 예측절차 고려 없음

(3) MIL-HDBK-217의 불만족

미 육군성(DOA)에서 RFP에 허용 없음

(4) COTS(commercial off-the-shelf)설비사용의 증대

COTS/NDI사용의 극대화가 미정부 방침

나. 신뢰성 시험과 측정에서의 문제

(1) Invalidity of assumption of exponential failure-time distribution

MIL-HDBK-781, IEC 605-7

Wong's roller-coaster curve

(2) Extrapolation from laboratory results to field reliability

aggravated stress, accelerated testing

(3) Expectation and achievement of high field reliability

(4) Fast technology and new product evolution and short lead-time markets

다. 정량적 정보의 효용화 문제

#### 4) 예측문제 해결방안

가. 고장물리에 의한 접근

나. 컴포넌트 고장률과 공정 수율과의 관계를 고려한 접근

다. MIL-HDBK-217 타입의 Pi-factors의 변화된 적용

라. 전 설비로 부터 외삽을 통한 설비예측

1979 US FAA R&M Planning Guide

MTBF 승수의 적용

마. 새로운 컴포넌트, 어셈블리/시스템 고장률 모델

roller coaster failure-rate model

Wong's new framework model

바. 사람에 기인한 오류/원인을 포함

사. 퍼지 로직의 신뢰성 및 위험평가

아. 베이저안 접근

자. 소프트웨어 신뢰성예측

차. 새로운 방법의 적용

Procedure III of MIL-HDBK-472의 스코어방법

#### 5) 신뢰성 시험과 스크리닝

목적, 방법, 가정, 해석, 한계등을 이해

가. 가속시험

나. ESS(Environmental Stress Screening)

#### 6) 사용현장 시험과 수행도 관측

가. Accumulated failure M(t) plotting and analysis

나. Performance parameter modelling and analysis

다. 자동 신뢰성 자료수집

라. Short-duration in-situ equipment testing

**7) 사용자의 업무**

가. Equipment records and historical data; traceability

나. Failure report forms

다. Failure data analysis

**8) 새로운 도전**

가. 고장자료의 수집분석을 위한 효율적인 시스템의 구축 및 유지

나. 이들 자료를 모든 경영활동에 충분히 활용

다. 신뢰성 예측기법의 개발 및 유지에 참여