Development of OMS/MP for the System Reliability

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Abstract. This work describes an essential process of reliability analysis in weapon systems. The OMS/MP providing essential data of RAM analysis must be prepared by user. However, data acquisition quantified by operational environment of the systems and related instructions are now insufficient to the reliable systems acquisition. OMS/MP based RAM factor is an essential requirements in reliability model analysis. The process of reliability analysis is also often done with an insufficient understanding of OMS/MP. This work proposed the improved reliability analysis process with RELEX. It is shown that the process is a good reasonable by its application of the weapon systems.

Introduction

It is required to develop OMS/MP(Operational Mode Summary/Mission Profile) that provides the goal of RAM analysis and fundamental data for ROC analysis by user. However, the insufficient work of data acquisition quantity due to operational environment and writing guidance caused user oriented product development and reliable weapon systems acquisition not to satisfy. As shown in Figure 1, User's OMS/MP from MAA(Mission Area Analysis) is informed to ILS office. It is provided as data for calculating RAM goal. Then, the calculated goal is applied to design weapon systems and develop ILS. User is required to include goal for operating availability in ILS factors of the request for military strength needs and to consider operating availability of any similar weapon systems. However, the most determination of OMS/MP based operating availability goals are not applied in design standards when developer analyzed requirement because of insufficient background data of them. In this respect, this work describes an essential process of reliability analysis in weapon systems. The improved reliability analysis process with reliability analyzing model(RELEX) is proposed. It is shown that the process is a good reasonable by its application of the weapon systems.

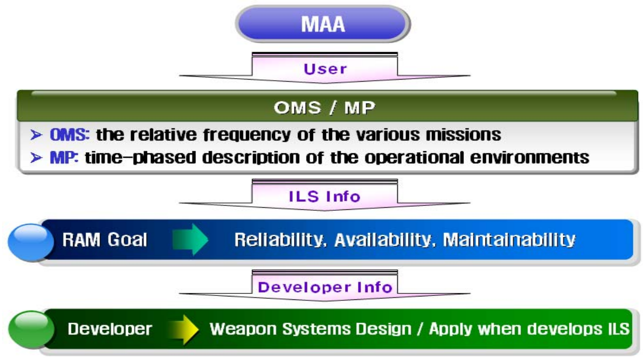

Figure 1. Relation between OMS/MP and Weapon Systems Acquisition

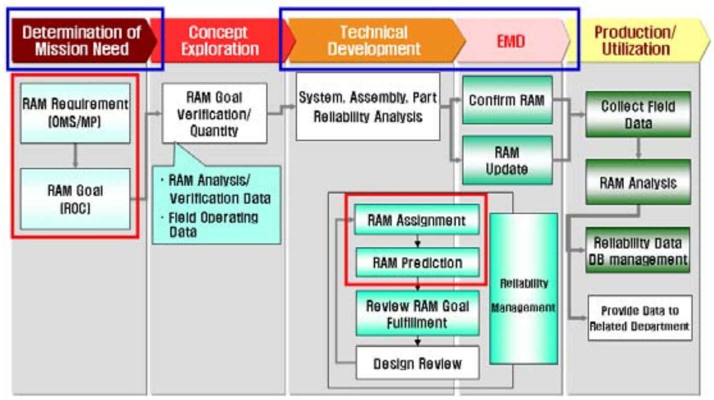

Figure 2. RAM task by Acquisition Levels of Weapon Systems

Reliability Analysis Process

As shown in figure 3, major factors and prediction range for reliability prediction is established by RAP(Reliability Analysis Process) through OMS/MP calculation, failure data collection and analysis. It is possible to predict reliability on the designated object through this and conduct analysis on the predicted results.

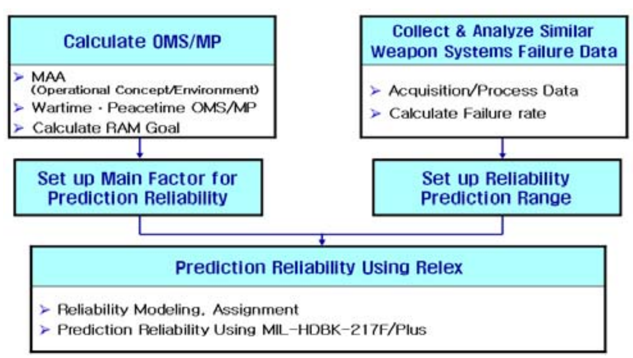

Figure 3. Reliability Analysis Process

OMS/MP Calculation

MAA(Mission Area Analysis) consists of a simulated combat scenario, an operational scenario and integrated MATRIX based on User's OCD(Operational Concept Document). When weapon systems developers calculate RAM, the mission function data can be checked by them of the weapon systems necessary for system development with MAA.

OMS/MP provides level requirements in terms of mission and function by arithmetic methods. OMS/MP is developed and provided as an appendix to the ORD[1]. The data classified war and peacetime is used as fundamental data for analyzing RAM. The peacetime OMS/MP is constructed in consideration of DOTMLPF(Doctrine, Organization, Training, Material, Leadership & Education, Personnel, Facilities). As shown in Figure 4, OMS/MP of the wartime is written based on operational area analysis data and combat/operational scenario which is completed in MAA. Factors used in the wartime OMS/MP are derived through an expert Delphi method, etc[2].

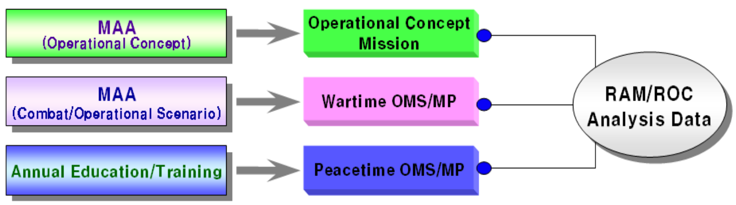

Figure 4. Derivation of OMS/MP

MAA. The operational concept of the MAA is described from the considerations of the ship's basic mission, weapon systems combat effect, limiting factors, battlefield functional role. And operational environment analysis is done by considering weapon systems operational process, security environment/future warfare condition, threatening assets, naval vision/roles, weather on operational areas. Combat scenarios describe time-phased and/or unit-typed weapon systems utilization when the war is to be fierce. Operational scenarios identify synthetic enemy's threat possible to happen by mission types. Then it specifies future battlefield aspects corresponded to current doctrines through war phase/time/assigned time by mission type. The integrated MATRIX combines combat/operational scenarios which specify operation type, time-phased reaction. It is converted into tactical/technical characteristics and quantity.

Peacetime OMS. By analyzing annual training and non-mission(Repair/RFS) times OT(Operating Time), AT(Alert Time), ST(Stand by Time), and TUT can be produced. The peacetime OMS is calculated with total time, maintenance time, non-mission time, training time, working time, non-working time. TDT(Total Down Time) is calculated by analyzing TMT(Total Maintenance Time) and TALDT(Total Administrative & Logistic Down Time). The OMS is completed if CT(Calendar Time) created from TUT and TDT. From non-mission period, underway and RFS periods are calculated from TUT(ST) and TDT(TMT+TALDT). Table 1 shows the peacetime OMS of the weapon systems.

Table 1. Peacetime OMS

Mission	TUT(hr)					TDT(hr)			CT (hr)
	Total	OT	AT	ST	Numer of mission[1)]	Total	TMT	TALDT[3)]	
Ship EX	A_1[2)]	A_1B_{11}	A_1B_{21}	A_1B_{31}	/mon				

SQ EX	A_2	A_2B_{12}	A_2B_{22}	A_2B_{32}	/mon				
FLT EX	A_3	A_3B_{13}	A_3B_{23}	A_3B_{33}	/qtr				
Joint EX	A_4	A_4B_{14}	A_4B_{24}	A_4B_{34}	/qtr				
Combined EX	A_5	A_5B_{15}	A_5B_{25}	A_5B_{35}	/yr				
Underway/RFS/Repair	A_6	-	-	A_6	-	E_1	$0.75E_1$	$0.25E_1$	
Total(hr)	A_7	OO	OO	OO	-	E_2	OO	OO	8,760

1 : Number of mission is changeable regarding EX plan.

2 : $A_1 = A_1B_{11} + A_1B_{21} + A_1B_{31}$, $E_1 = 16C_2 + (4/3 \times dD)$. A_2, A_3, A_4, and A_5 uses same methods (B_{ij} : weight of underway time)

3 : Total maintenance hour of each EX × 25%

Peacetime MP. It describes the required mission function regulations and quality of operations by mission types of device utilization to be conducted annually in the training/EX and device maintenance plan. This also includes maneuvering distance, rounds of fire, operational time of control devices, and survival time regarding operational missions. Table 2 indicates the peacetime MP that AT is applied as a survival time.

Table 2. Peacetime MP

Remarks	AMD(km)	MMD(km)	Rounds(1/yr)	OCD(hr)	ST(hr)
Ship EX	F_1	F_{11}	F_{12}	F_{13}	F_{14}
SQ EX	F_2	F_{21}	F_{22}	F_{23}	F_{24}
FLT EX	F_3	F_{31}	F_{32}	F_{33}	F_{34}
Joint EX	F_4	F_{41}	F_{42}	F_{43}	F_{44}
Combined EX	F_5	F_{51}	F_{52}	F_{53}	F_{54}
Total	F_6	OO	OO	OO	OO

1 : AMD(Average Maneuvering Distance) and MMD(Maximum Maneuvering Distance) are calculated on the basis of 27km/hr and 54km/hr respectfully.

2 : $F_1 = 27 \times A_1$, $F_{11} = 54 \times A_1$, $F_{13} = 1.25 \times A_1$, $F_{14} = A_1B_{21}$. F_2, F_3, F_4, and F_5 are also calculated same way.

Wartime OMS. It is calculated from the combat/operational scenarios, wartime operational concept and missions by operation levels. In this work, annual 40 cycles of the OMS are given by 9 day cycle considered 3 day combat and 6 day readiness. 6 day readiness period is divided into ST and TDT. Working time factor(G_{ij}) is calculated as a similar method as the peacetime OMS. This uses Delphi method that is subject to operating time data measured through exercising OPLANs and users servicing over 10 years on ships. When anticipating a 9 day combat scenario, 9 day wartime OMS is TUT$\times G_{ij}$. Table 3 shows 365 day OMS given by multiplying 40. It can be calculated straightforwardly by TDT=TT(1-Ao) because operating possibility(Ao=TUT/TT) is same in both wartime and peacetime. TDT is applied only during readiness period because it can only conduct its missions if devices are operational during wartime[3].

Table 3. Wartime OMS

Remarks	TUT(hr)				TDT(hr)
	TUT	OT	AT	ST	
Tactical Manuever of ships	H_1	H_1G_{11}	H_1G_{12}	H_1G_{13}	-
Stand by at Assembly place	H_2	H_2G_{21}	H_2G_{22}	H_2G_{23}	-
Offensive Ops	H_3	H_3G_{31}	H_3G_{32}	H_3G_{33}	-
Defensive Ops	H_4	H_4G_{41}	H_4G_{42}	H_4G_{43}	-
Readiness	H_5	-	-	H_5	H_6

Wartime MP. It is calculated through rounds of fire and maneuvering distance by operational modes and mission types based on combat/operational scenarios of MAA. Rounds of fire are assumed in proportion to the combat intensity. Calculating process of the combat intensity and rounds of fire is shown in Figure 5. The combat intensity changes in time, so it has to be calculated considering damage levels of enemy surface ships and personnel. Enemy warships and personnel to be destroyed on day X(day X explains damage levels of enemy warships and personnel) are calculated from successively of friendly forces' operations. 50% are applied on the offensive operations and 30% in defensive operations.

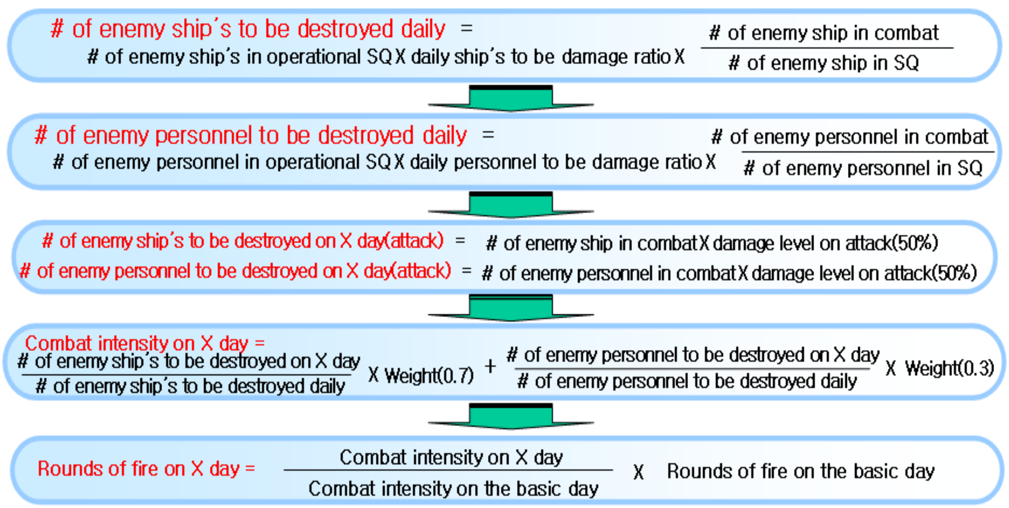

Figure 5. Calculating process of Combat Intensity and Rounds of Fire

Maneuvering distance can be calculated through multiplying average maneuvering speed by working time. The ground factor is earned from the Delphi method of a user over 10 years of ship experience. The ground factor varies on the maritime conditions. This study applies 1 to wave height 0 ~ 1m for convenience. Table 4 shows wartime MP by estimating average maneuvering distance and maximum maneuvering distance each as 27km/hr and 54km/hr respectfully.

Table 4. Wartime MP

Remarks	AMD(km)	MMD(km)	Rounds(1/yr)	OCD(hr)	ST(hr)
Ships maneuver	J_1	J_{11}	J_{12}	J_{13}	J_{14}

Stand by at Assembly place	J_2	J_{21}	J_{22}	J_{23}	J_{24}
Offensive Ops	J_3	J_{31}	J_{32}	J_{33}	J_{34}
Defensive Ops	J_4	J_{41}	J_{42}	J_{43}	J_{44}
Readiness	J_5	J_{51}	J_{52}	J_{53}	J_{54}

Calculating RAM Goal

In the acquisition program phase, the quantity of RAM goal suitable for the operating system should be set up through maintenance concept and functional analysis. This is considered by the operations concept and circumstance of weapon systems. Process of RAM goal establishment is shown in Figure 6[4]. RAM goal methods of establishment include considering similar weapon systems analysis based on units, a corps operating goal, and combat readiness(operating ratio) and a goal utilizing common use software. User calculates reliability and maintainability based on analysis on operating data (mission profile, training, maintenance etc) of currently operating ships, and these are utilized when goal is set up A_0[5].

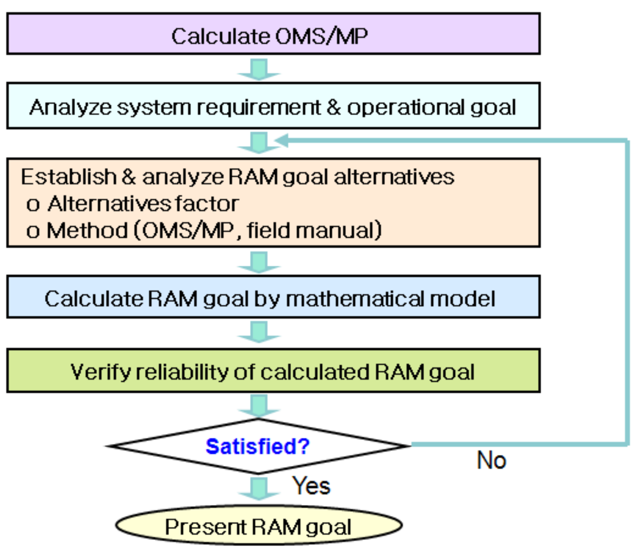

Figure 6. Establishment Process of RAM Goal

RAM(Reliability, availability and maintainability) can be calculated easily by applying TUT, TDT, maneuvering distance, and rounds of fire earned of the war and peacetime OMS/MP to RAM goal formula in Table 1. Reliability is probability to conduct intended performance during a designated period without failure within a given condition of the system(device) and parts. And Mission reliability means probability to operate during a designated period without failure. Reliability is given by MTBF(Mean Time Between Failure), MKBF(Mean Kilometers Between Failure), and MRBF(Mean Rounds Between Failure). Availability is a device being used in a designated condition without plan maintenance that is in possible status of utilization. This is used to calculate inherent availability(A_i), achieved availability(A_a), operational availability(A_o). Maintainability is probability to restore performance as it was by repairing in given time with possible procedure and resources by a designated technicians, and it determines MTTR(Mean Time To Repair) and MR(Maintenance Ratio).

Collect and Analyze Failure Data of Similar Weapon Systems

OO weapon systems, currently being used in the navy, were developed by McDonald Douglas company, USA in 1971.Where it was used as surface to surface missiles in the US Navy. OO weapon systems have serviced to OO navy since 1979. They were used as ground to surface, air to surface, and sub to surface missiles. OO Naval Logistic Command Ordnance and Ammunition Depot inspects and repairs OO weapon systems. When inspection cycle comes, they conduct functional inspections of the missiles by designated check-off lists. Then transfer the weapon systems to the maintenance shop and replace them if those missiles fail performance tests. As shown in Table 5, target seekers, midcourse guidance units and R/D altimeters are most problematic parts in order. They hold over 84% of the overall failure rate. It is presumed that target seekers and midcourse guidance units include too much circuit cards and electronic parts for signal process.

Table 5. OO weapon systems Failure Statistics('01~'06)

Remark	'01	'02	'03	'04	'05	'06	Total
After Body Relay	0	0	0	0	0	1	1
Battery	0	0	0	0	0	2	2
BSTR Separa' Relay	0	0	0	0	1	1	2
Elect' Control Amp'	0	0	0	1	1	0	2
Eng' Start Relay Panel	0	0	0	2	0	1	3
Midcou' Guidance Unit	3	5	5	0	7	0	20
Gyro Relay Panel	0	0	0	0	0	1	1
R/D Altimeter	0	3	5	2	4	5	19
Sustainer Section	1	0	1	1	0	1	4
Target Seeker	16	11	19	19	26	14	105
Turbo Jet Engine	2	0	0	1	3	5	11
Total	22	19	30	26	42	32	171

Establishing Reliability Prediction Range

Missiles in canister are loaded in a ship to destroy or neutralize enemy ships in a long distance out of LOS. The missiles consist of the completed assembly flying after launch and the launching tube assembly helping missiles to be launched normally. The launching tube assembly consisting of mechanical parts has less frequency of failure than that of the completed assembly including many electronic parts. This work, therefore limits reliability analysis to the completed assembly. And saving reliability on each subassembly is estimated by applying output of the OMS/MP.

Reliability Prediction Utilizing Reliability Analysis Model

General procedure of reliability prediction is by inputting information of the parts that construct the system and the operational environment. Then calculate the failure rate of each part. MTBT calculated from the failure rate is utilized for LSA(Logistic Support Analysis) and design. Figure 7 indicates a specific process of reliability prediction. Part Stress Analysis prediction method of MIL-HDBK-217F is used to predict reliability. Failure rate of other mechanical and electronic components that are not provided in MIL-HDBK-217F uses empirical data provided in NPRD-95.

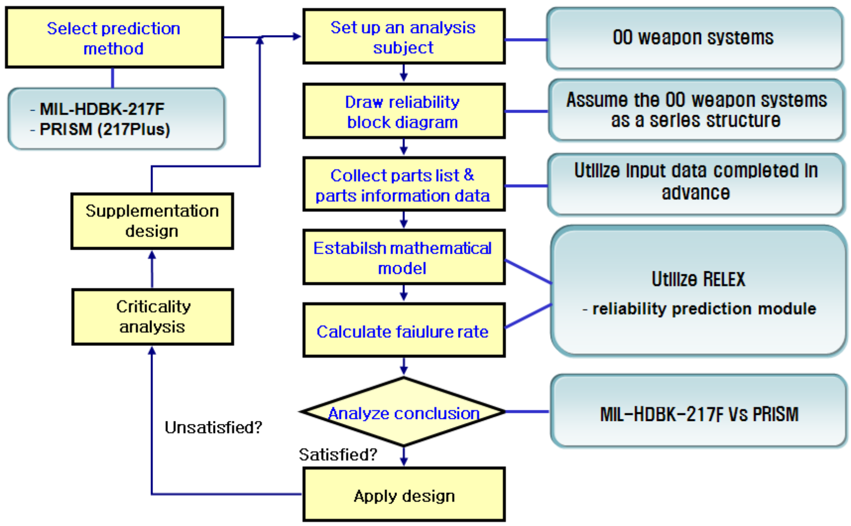

Figure 7. Process of Reliability Prediction

Missile Flight(M_F), Naval Unsheltered(Nu), and Ground Benign(G_B) are 3 types of missions which Missiles in canister have, accordance with temperature conditions and operating circumstances shown in Table 6. Reliability of missiles in canister is referred to as device reliability of inserted missiles. Stored reliability is calculated from this device reliability[6].

Table 6. Operational Temperature & Condition

Device name	Operating Circumstances		Analyzing Temparature Condition	Note
Missile Assembly (In-flight)	operating	missile flight(M_F)	OO	In-flight
Inserted Missile (shipped/stored)	operating	naval unsheltered(N_U)	OO	On deck(OO%)
	dormant	ground benign(G_B)	OO	Stored Maintenance(OO%)

Reliability prediction as shown in Figure 8 indicates MIL-HDBK -217F(N2) of RELEX Studio 2006 calculation model with input temperature parameter OO in missile flight circumstances. It pre-inputs parts data of searching devices, electronic wave altimeter, and guidance control unit which are level 4 of the completed assembly[7].

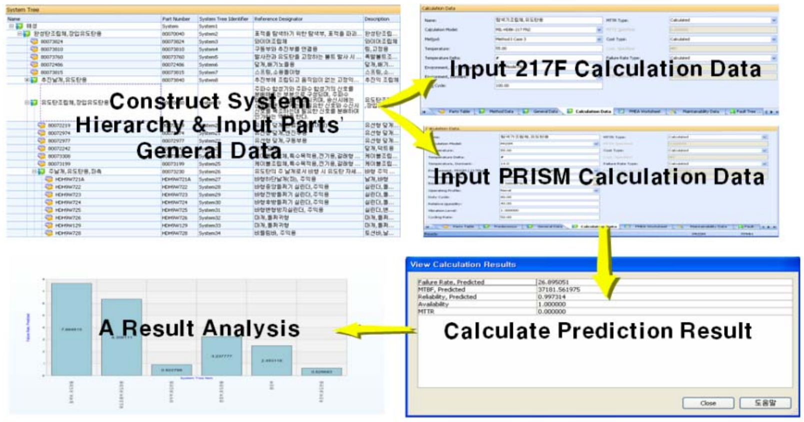

Figure 8. Application of RELEX

Analyzing Reliability Prediction Result

MTBF of missiles subsystems was somewhat different according to the prediction models. For example, PRISM has 39,271 hours while MIL-HDBK-217F has 36,648 hours. Search and guided control section including multiple circuit cards showed high failure rate. Difference shown in engine/drive sections is due to a digital controller whish having functional characteristics being influenced by environments.

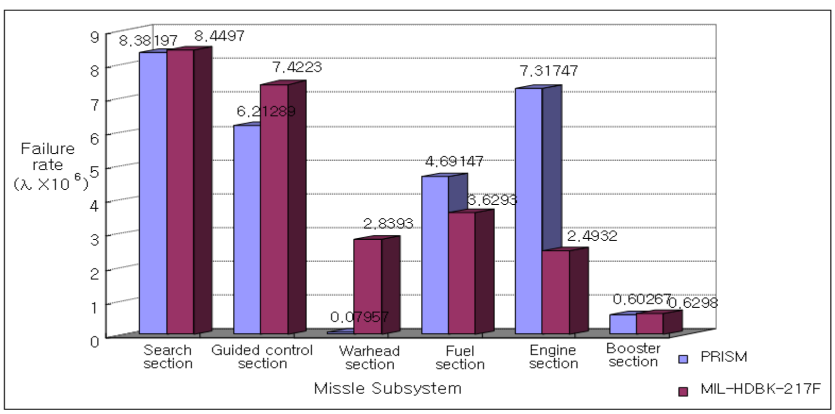

Figure 9. Failure Rate Distribution of Missle Subsystem

As shown in figure 10, the failure reason due to parts(22%) of the electronic system is less rather than the other factors(76%). Upgraded 217Plus may be more accurate reliability prediction and analysis since process grade, battlefield operating data, and S/W failure rate are applied to the basic failure rate[8].

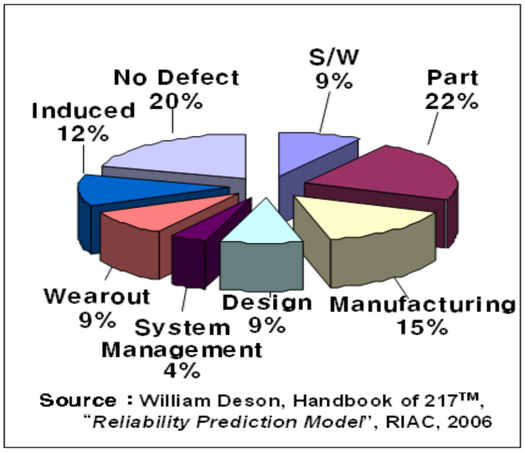

Figure 10. Major Reasons of Electronic System's Failure

Conclusion

The OMS/MP which provided essential data of RAM analysis & ROC derivation should be prepared by user. This work describes an essential process of reliability analysis in weapon systems. The improved reliability analysis process with reliability analyzing model(RELEX) is proposed. It is shown that the process is a good reasonable by its application of the weapon systems.

Reference

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