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Reliability analysis of Electronic Control Unit and Remote Unit used in Decoy Launcher Defence System

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ABSTRACT

With the development of technology, effective countermeasures of decoy launcher are developed. Decoy Launcher Defence System (DLDS) designed to detect, to track and to localize the incoming Decoy from the enemies and it is a countermeasure system. The system offers a complete solution to detect and locate an incoming Decoy and provides highly effective defence for the system. The DLDS shall enable timely defence against incoming Decoys at sufficient range from the submarine to guarantee safety and survivability of own platform. Controlling of decoy launcher plays a crucial role in launching and firing of Decoys. For controlling the Decoy Launcher, two control units are there. They are Electronic Control Unit (ECU) and Remote Unit (RU). ECU is manually controlled and it acts as a master controller for the launcher. RU is controlled by directors through remotely (infrared signals). It is necessary to improve the reliability of the control units. In order to obtain the reliability of ECU and RU of DLDS, in this paper developed the Reliability Prediction, Reliability Block Diagram (RBD) and Failure Mode Effect and Criticality Analysis (FMECA). Reliability Analysis gives the Prediction of the failure Rate and Mean Time Between Failures (MTBF). Reliability Prediction obtained in accordance with MIL-HDBK-217F2. Reliability Block Diagram (RBD) used to know the parts reliability how it contributes to success or failure of a system using logical operations of the system. FMECA used to obtain the failure modes of the components, their effect on system, identifies the criticality and corresponding changes are made in the design to reduce the failure modes. The procedure for performing a failure mode effects and criticality analysis developed by MIL-STD-1629. To control these failures proper methods are considered to improve the reliability of system. The reliability analysis is carried out using ITEMSOFT Tool.

***Keywords**— Reliability prediction, FMECA, RBD, MIL-HDBK-217Fn2*

1. INTRODUCTION

Decoy launcher [1] provides a step increase in ship protection and shall enable high timely defence against enemies. Decoy controlling places a very crucial role in launching and firing and it provides a certain level of security to the system. The control unit in Decoy launcher manage the commands, direct or regulates the behavior of the systems. Decoy launcher consists of 2 control units. They are ECU and RU. ECU is manually controlled whereas RU controlled by infrared signals. Functions of ECU and RU are similar. It is necessary to improve the reliability of the control units in Decoy Launcher.

1.1 Electronic control unit

The ECU is a line replaceable unit fitted on the launcher. The launcher can be fired locally from this unit. ECU acts as the master controller for the decoy launcher. Capable of controlling launcher independently by means of individual push buttons and controlled keys. ECU provides communication with RU. The ECU hardware is integrated with the following hardware:

(a) ECU LD Card
(b) ECU PU Card
(c) Power Supply Card

- **Processing Unit**: The PU card is used for displaying the status of the Launcher and to provide communication between the control units. The output of the PU card conveying the status of the launcher is sent to the RU.
- **Functions of PU:** Generate available/ready status signals and also sent from this card. Logical Device (LD) has a monostable multi-vibrator which gives timing to the firing pulses in the decoy. Generate +5V, -5V, 3.3V, & 5V Ref power supplies required to its internal circuitry.

1.2 Power supply unit

It acts as an interface between the decoy power supply and power supplies of the various cards. It provides input power supply to LD and PU cards 24V DC. The power supply unit needs to operate successfully for providing continuous power supply to ECU.

- **Functions of Power supply unit:** Distribute 24V DC supply to ECU PU Card and ECU LD Card. Protects against spurious voltages and currents.
- **Logical Device:** The LD card is used to control the firing and to generate the logical signals.

- **Functions of LD** are: It takes inputs from the ECU and Processes input signals and converts them into digital signals. Takes 24V DC and converts it into 5VDC/50mA.

1.3 Remote unit

It is used to operate the Decoy Launcher from a position other than from the launcher i.e., it can be used to operate and control launcher (Port/Starboard) remotely. Capable of controlling each launcher independently by means of individual push buttons and controlled keys. Receives commands, generate fire commands if in REMOTE mode.

The RU hardware is integrated with the following hardware:

(a) RU LD Card
(b) RU PU Card
(c) Power Supply Card

1.4 The interface between RU and ECU

The ECU (Port/Starboard) communicates with RU and Launcher via RS485 link. If the link between the LCU and RCU fails, firing cannot be done through the Launcher because the RU will have no data about the status of the ECU. If the link between the ECU and Launcher fails, the Launcher will have no data about the status of the ECU. However, it is still possible to execute the firing through the RU when the link between ECU and RU is established.

In this paper, models for Reliability analysis of ECU and RU of the Decoy Launcher using Reliability Prediction (RP), Reliability Block Diagram (RBD) and Failure Mode Effect Criticality Analysis (FMECA) are developed. To reduce the failure rate and to obtain a robust design. By these methods, Reliability to be improved.

2. RELIABILITY PREDICTION

Reliability prediction is one of the fundamental models of reliability analysis. This analysis can predict the failure rate of parts and total system reliability. “This type of prediction is used to find out design possibilities, compare design alternatives, determine attainable failure areas, trade-off system design factors, and track reliability.” [2] The effect of proposed design changes of the system is obtained by showing the difference between the existing and proposed designs of reliability prediction. The design ability is to maintain an acceptable level of reliability under environmental changes can be accessed through reliability predictions. Results from the reliability prediction may find a necessity for some redundant systems, back-up systems, subsystems or component parts. A reliability prediction can assist in evaluating the importance of reported failures Standards Based Reliability Prediction such as MIL-217, Bellcore and Telcordia provide the MTBF and failure rate.

2.1 MIL-HDBK-217

MIL-HDBK-217[3] is a worldwide handbook for reliability predictions. It is used by both commercial industries and the defense industry. This handbook provides a series of experimental failure rate models which covers all electrical/electronic parts, providing 14 separate operational environments, such as ground mobile, naval shelter, naval unsheltered etc. There are two major prediction approaches The Part Stress technique and the Parts Count technique. As the names indicate, the Part Stress analysis provides information about the stress levels on each part to determine their failure rates. The Parts Stress Analysis method is used widely and is applicable when the design is near to completion and a detailed parts list, or Bill Of Materials (BOM), plus component stresses are available whereas the Parts Count analysis accept average stress levels in early design phase due this high failure rates obtained but part count analysis requires less information as compared to part stress method.

Typical MIL-217 Failure Rate Model

A sample MIL-217 failure rate model for a diode with high frequency is:

$$\text{Failure rate} = \lambda_b \text{ x } \pi_t \text{ x } \pi_a \text{ x } \pi_r \text{ x } \pi_Q \text{ x } \pi_e \text{ Failures/Million Hour} \qquad (1)$$

Where,

λ_b= Base failure rate.
π_t= Temperature factor.
π_a = Application factor (linear, switching, etc).
π_r = Power rating factor.
π_Q = Quality factor.
π_e = Operating environment factor.

Failure rate of a diode with low frequency has a MIL-217 model

$$\text{Failure Rate} = \lambda_b \text{ x } \pi_t \text{ x } \pi_s \text{ x} \pi_c \text{ x } \pi_Q \text{ x } \pi_e \text{ Failures/Million Hours} \qquad (2)$$

Where,

π_s = The electrical stress factor
π_c = contact construction factor
π_e = Operating environment factor.

The above listed π factors are based on a simple component. There are also π factors for items such as learning factor, die complexity factor, manufacturing process factor, device complexity factor, programming cycle factor, package type factor, etc. Each component or part group and its associated subgroup has a base failure rate plus numerous π factor tables, unique to that component or part.

2.2 Reliability Prediction of ECU and RU

Reliability Prediction for ECU and RU is obtained by MIL-HDBK-217F based on Bill of Materials (BOM). For the reliability prediction of ECU and RU, some assumptions are as per manufacturer. They are:

(a) The environmental factor for ECU is Naval, Unsheltered and RU is Naval, Sheltered.
(b) The operational temperature for Reliability Prediction is 55° C.
(c) The operational Duty cycle is 100% continuous.
(d) Considering nominal stress on each component of 0.5
(e) The quality factor is selected for the component as per the engineering judgment and information provided in the datasheet.

2.3 Reliability prediction Results

The failure rate of the overall electronic control unit system is calculated to be 72.325 failures per million hours, which results in an MTBF of 13,826.47million hours as shown in table 1. The failure rate of the overall remote unit is calculated to be 41.02 failures per million hours, which results in an MTBF of 24,269.488 million hours as shown in table 2.

Table 1: Reliability prediction of ECU

Name: ECU of Decoy launcher
FR: 72.325, **MTBF:** 13,826.47

Block	Description	Quantity	Failure Rate	MTBF
1(a)	Processing Unit	1	46.519	21,496
1(b)	Logical Device	1	18.856	53,033.157
1(c)	Power Supply Unit	1	6.949	1,43,905
			72.325	

Table 2: Reliability prediction of Remote Unit

Name: RU of Decoy launcher **FR:** 41.02, **MTBF:** 24,269.488				
Block	**Description**	**Quantity**	**Failure Rate**	**MTBF**
2(a)	Processing Unit	1	23.1351	43,224.545
2(b)	Logical Device	1	5.123	95,198.1206
2(c)	Power Supply Unit	1	0.375	2669945.5
2(d)	Auto fired LD	1	12.571	79544.75
			41.02	

3. RELIABILITY BLOCK DIAGRAM

"RBD will be developed to explain about the redundancy of a system in achieving objectives by forming the mathematical methods" [4] The RBD is a graphical representation of how individual subsystems and/or equipment interact to achieve the operational objective of the system. 'The RBD is modelled using Blocks, which represents individual component failures, connected either in series or parallel arrangement" [5]. A Series connection represents a single continuous link in which failure of one block will contribute to the elimination of one single success path from the input node to the output node. A Parallel connection is used for redundancy configuration that requires multiple or all parallel paths from start node to the output node to fail to contribute to the unsuccessful system operation or system failure.

Depending on the complexity of the system, the RBD will be a combination of series and parallel configurations to illustrate the different success paths for the successful operation of the system from the left-hand side of the input node towards t right side of the output node of the diagram. For the successful operation of the system minimum, one path must be successful from input to the output node.

3.1 Inputs required for RBD

(a) MTBF calculated from Reliability Prediction.
(b) Block logic from the system architecture.
(c) System functional description.

3.2 Reliability Block Diagram ECU and RU Results

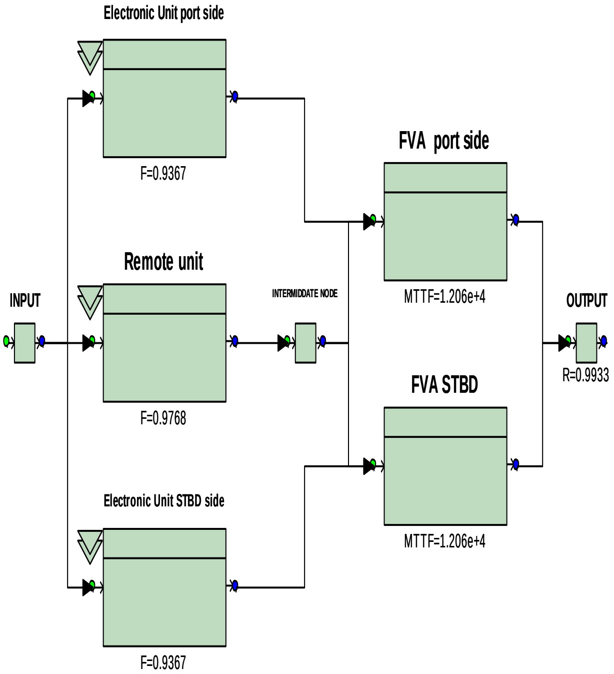


Fig. 1: RBD of ECU and RU

Reliability of ECU and RU using RBD is R(t)=0.9933

4. FAILURE MODE EFFECT AND CRITICALITY ANALYSIS (FMECA)

FMECA is a combination of FMEA and criticality analysis. In the year 1950 FMEA was introduced. FMEA is a deductive analysis that identifies and evaluates the failure of a product, the effects of the failure and gives the actions that could reduce failures. Failure Modes Effects and Criticality Analysis (FMECA) will be conducted during the design phase and updated in subsequent Construction/T&C phase, to provide a rigorous assessment of the effects of each credible component failure mode at a different level of the system intermediate level and system level. "FMECA starts with system definition, provides identification of internal and interface functions, expected to perform indenture levels, system restraints and failure definitions at each phase and operation model [6]. Identify all potential items and interface failure modes land define their effects on the immediate function or item, on the system and on the mission to be performed. Assign severity ranking to each failure mode based on their effects on the system and mission phase takingMIL-STD-1629A as reference. "Severity classification is given as [7]:

(a) **Catastrophic:** A failure which leads to complete loss of system (Aircrafts, missile, ship, launchers etc.)
(b) **Critical:** A failure which leads to serious injury, high loss of property, or total system damage which will result in operational loss.
(c) **Marginal:** A failure which leads to cause small injury, loss of property is very less, or small damage to the system which will result in delay or unavailability of system or mission degradation.
(d) **Minor:** A failure may not seriously effect to cause injury, system damage or loss of property which will result in repair action or unscheduled maintenance

Evaluate the criticality number (C_m) using the failure rate (λ_i) of the item, failure mode ratio (α) and conditional probability (β) of the mission loss because of that item failure within the mission time (t).

$$C_m = \beta * \alpha * \lambda_i * t$$

4.1 FMECA of ECU and RU

By studying the operation and its functions of ECU and RU, the failure modes and its effects on the system are obtained. Based on these failure modes the severities are assigned. If these causes of failures are controlled then take the measures to prevent the failure modes which reduces the criticality, thus it increases the safety of the system. To obtain the FMECA it requires the inputs.

4.1.1 Inputs required for FMECA:

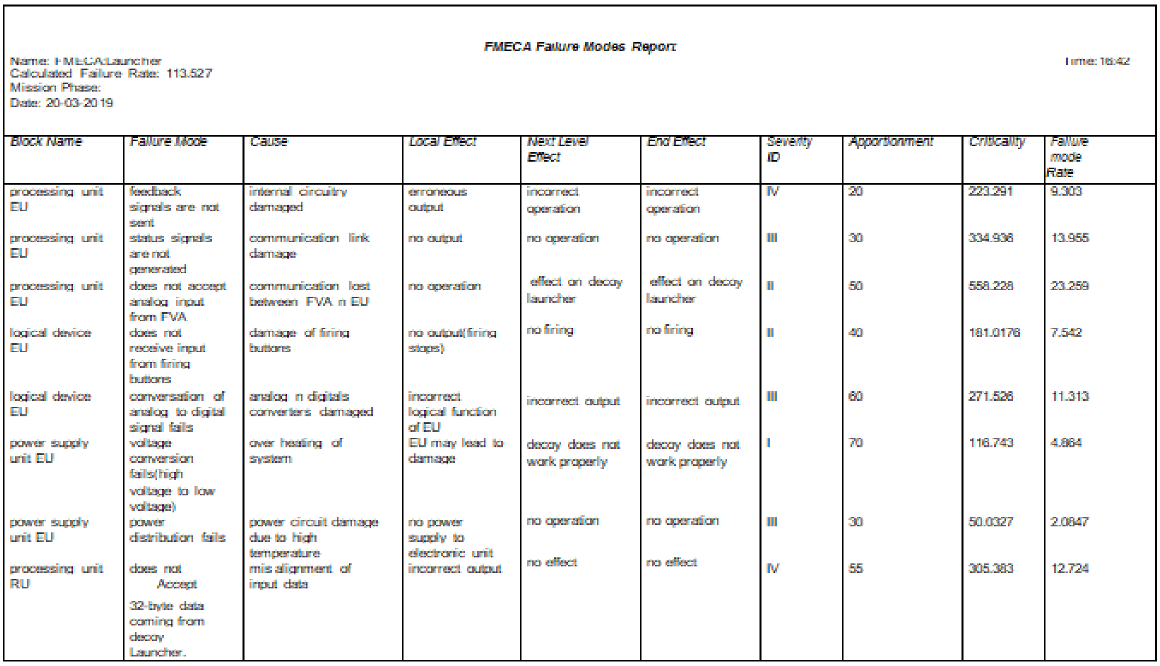
(a) System functional description.
(b) Bill of Materials.
(c) Failure rate from Reliability Prediction.

From these inputs, FMECA is conducted and results [8] are shown below in table 3.

5. CONCLUSION

The main aim of this paper is to improve the reliability of ECU and RU of Decoy Launcher. In this paper Reliability prediction, Reliability Block Diagram and Failure Mode Effect Criticality Analysis are developed. By using Reliability Prediction failure rate of each component are obtained. From these failure rates, developed the RBD and FMECA identify the failure modes and its effects of the system. so that these potential failures can then be designed out, which reduces the system failures and improves reliability.

Table 3: FMECA Results

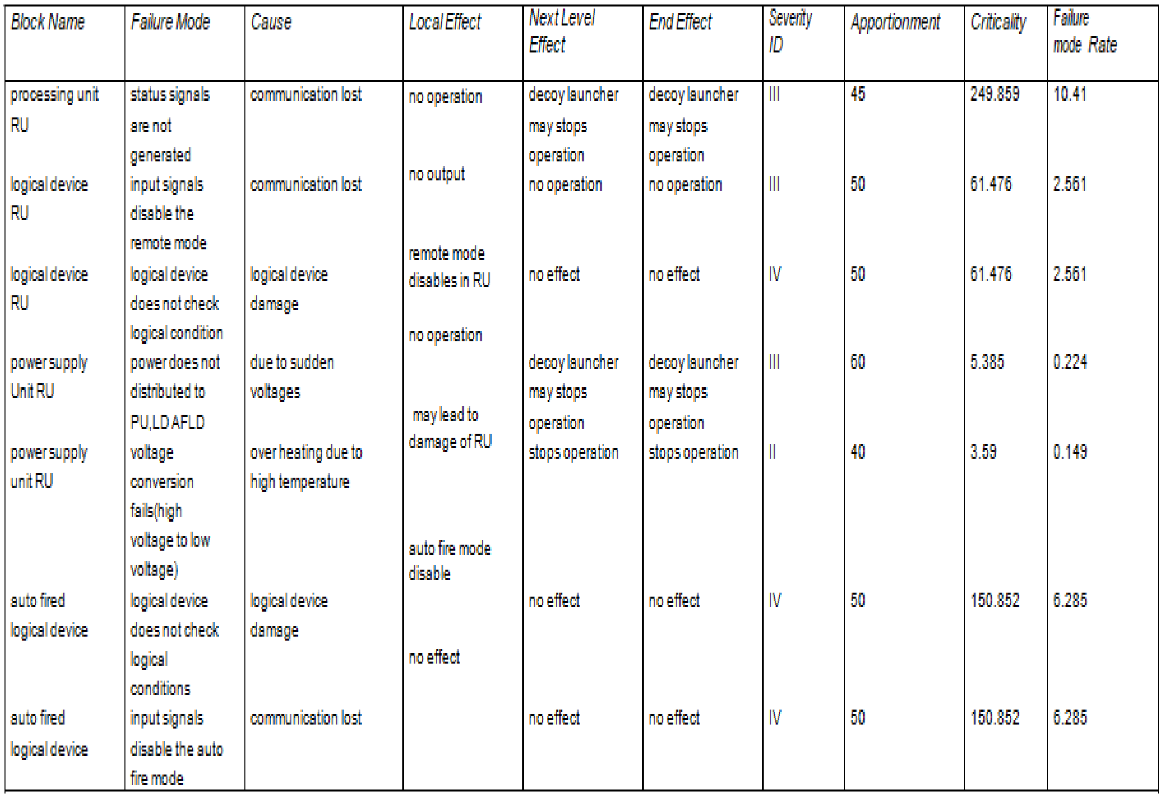


FMECA Failure Modes Report

Name: FMECA:Launcher
Calculated Failure Rate: 113.527
Mission Phase:
Date: 20-03-2019

Time: 16:42

Block Name	*Failure Mode*	*Cause*	*Local Effect*	*Next Level Effect*	*End Effect*	*Severity ID*	*Apportionment*	*Criticality*	*Failure mode Rate*
processing unit EU	feedback signals are not sent	internal circuitry damaged	erroneous output	incorrect operation	incorrect operation	IV	20	223.291	9.303
processing unit EU	status signals are not generated	communication link damage	no output	no operation	no operation	III	30	334.936	13.955
processing unit EU	does not accept analog input from FVA	communication lost between FVA n EU	no operation	effect on decoy launcher	effect on decoy launcher	II	50	558.228	23.259
logical device EU	does not receive input from firing buttons	damage of firing buttons	no output(firing stops)	no firing	no firing	II	40	181.0176	7.542
logical device EU	conversation of analog to digital signal fails	analog n digitals converters damaged	incorrect logical function of EU	incorrect output	incorrect output	III	60	271.526	11.313
power supply unit EU	voltage conversion fails(high voltage to low voltage)	over heating of system	EU may lead to damage	decoy does not work properly	decoy does not work properly	I	70	116.743	4.864
power supply unit EU	power distribution fails	power circuit damage due to high temperature	no power supply to electronic unit	no operation	no operation	III	30	50.0327	2.0847
processing unit RU	does not Accept 32-byte data coming from decoy Launcher.	mis alignment of input data	incorrect output	no effect	no effect	IV	55	305.383	12.724



Block Name	*Failure Mode*	*Cause*	*Local Effect*	*Next Level Effect*	*End Effect*	*Severity ID*	*Apportionment*	*Criticality*	*Failure mode Rate*
processing unit RU	status signals are not generated	communication lost	no operation	decoy launcher may stops operation	decoy launcher may stops operation	III	45	249.859	10.41
logical device RU	input signals disable the remote mode	communication lost	no output	no operation	no operation	III	50	61.476	2.561
logical device RU	logical device does not check logical condition	logical device damage	remote mode disables in RU	no effect	no effect	IV	50	61.476	2.561
power supply Unit RU	power does not distributed to PU,LD AFLD	due to sudden voltages	no operation	decoy launcher may stops operation	decoy launcher may stops operation	III	60	5.385	0.224
power supply unit RU	voltage conversion fails(high voltage to low voltage)	over heating due to high temperature	may lead to damage of RU	stops operation	stops operation	II	40	3.59	0.149
auto fired logical device	logical device does not check logical conditions	logical device damage	auto fire mode disable	no effect	no effect	IV	50	150.852	6.285
auto fired logical device	input signals disable the auto fire mode	communication lost	no effect	no effect	no effect	IV	50	150.852	6.285

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