# Reliability and Availability of the Coastal Missile Defence System

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**Abstract:** Reliability is one of the main salient assets of modern weapon systems. The estimation of the failure rate of the major subsystems of military defence systems is of utmost importance in the design of any country's overall defence system. The results of a study to estimate the failure rate of the main computer system of the launcher of a shore to sea missile launcher is presented in this study. The effect of this failure rate on the reliability of the launcher and the overall availability of the missile guidance, launch and control system are studied considering the vast region to be covered along the Persian Gulf and the Oman Sea area by such a defence system. Since aging of parts reduces a system's availability, the availability of the coastal missile defence system is studied based on the availability of each subsystem indicating the extent of work required for the reliability growth of the missile defence system along the coast. [Journal of American Science 2010;6(10):612-616]. (ISSN: 1545-1003).

**Key words:** Reliability estimation, Failure rate, Coastal defence system, Availability

## NOMENCLATURE

The symbols used throughout the paper are as follows:

MTTF = Mean Time to Failure in Hours
GM = Ground Mobile Conditions
ML = Missile Launch Conditions
$\lambda$ = Failure rate in Failures Per Million Hours
A = Availability

## 1. Introduction

Reliability indices are the most important measures available in the engineering and management of military defence systems. The successful deployment of missile defence systems highly depends on the proper understanding and use of reliability indices and reliability growth techniques. In general, reliability is defined as the probability of successful operation of a mission over a specified mission period and under predefined conditions. Reliability studies not only affect the successful operation of military defence systems, but they also have extensive application in the analysis, design, prototyping, manufacturing, testing, storing, field deployment, and maintenance and repair of such systems.

Meeker (1985) discussed the laboratory test facility at the pacific missile test center where measurements of the mean time to failure (MTTF) of missiles carried by aircraft are measured. In this laboratory, electrical, thermal and vibration stresses on the missile are reproduced in order to expose the weapon system to more realistic test conditions.

In another study, Elliot (1985) reported on the use of parametric and non-parametric techniques to analyze in-service data on two types of air-to-air guided missiles each type produced by two different manufactures. In order to detect and evaluate the presence of early failures and the 'useful life' period, Weibull analysis was used in this study. The non-parametric technique consisted of hypothesized extension of the factory environmental stress screening at the full assembly level. The mean-time-to-failure (MTTF) of the inventory was calculated. Then increments of time were taken off each missile and the MTTF of the new hypothesized inventory was calculated to see the change in MTTF as a function of additional screening time. They concluded that there is a need for stress screening at the full assembly level.

Li and others (2009) performed a detailed reliability analysis on the power equipment of a certain new ground-to-air missile weapon system, including the main engine generating system and external power supply system which contains the generator set, the control device, the junction box and the cable. They also obtained the reliability model of this power equipment according to its instance in battle and training.

Both experimental and theoretical approaches to reliability estimation and lifetime prediction may be used in the analysis and design of reliable coastal missile defence systems. The present study relies on failure rate estimation based on MIL-HDBK-217F (DOD 1995), and the Nonelectronic Parts Reliabilty Data (RAC 1995).

## 2. The Coastal Missile Defence System and its Availability

The coastal missile defence system is a vital part of the overall missile defence system of the country. Due to the strategic importance of the Persian Gulf and the Oman sea, the coastal missile defence system plays a highly important defence role. The system is usually composed of several missile sites each responsible for the coverage and protection of a given section of the coastal waters. Each site consists of several subsystems responsible for command, launch, guidance and control of the system. As the subsystems are composed of parts which have a limited lifetime, the overall system is of limited reliability. It may even be the case that some of the subsystems fail due to experiencing overstresses that may lead to early wearout and/or failure. Should this condition coincide with the need to fend off a potential threat by deploying the missile site, we may experience a tragic condition which could have grave consequences. The consequences may include damage done to the armed forces, the destruction of vital assets and strategic points in the country, failure of the mission of the defence forces, loss of opportunity to fend off the enemy approaching our coastal regions, and even the potential infiltration of the enemies into our land territories. However, the successful operation of the coastal missile defence system on certain strategic targets may hinder the enemy from further attacks.

Iran possesses around 5440 Kilometers of borders. About 740 Kilometers of this is at the Caspian sea and about 2440 Kilometers is in the Persian Gulf region. The extent of this region and the strategic position of the Persian Gulf make the reliability and availability of Iran's coastal missile defence system vital to her integrity.

The present study reports results of the reliability estimation of the main computer of a missile defence system and the effect of the availability of each site on the availability of the overall coastal missile defence system given the conditions along the coastal regions of the Persian Gulf and the Oman Sea.


Fig. 1 The coastal regions of the Persian Gulf and the Oman Sea

## 2. Reliability Estimation

Even early in the design stage and in the absence of any physical prototypes, a product's reliability may be estimated using existing failure rate databases such as MIL-HDBK-217F (1995), 217Plus, SPIDR, PRISM, FIDES, Telcordia SR-332, EPRD, HRD4, CNET, 299B, NSWC, NPRD, etc. Usually a system must undergo a reliability program before it matures into a high reliability product. Early life reliability predictions may be used to decide whether a product meets a specific early life reliability requirements or it should undergo reliability growth programs. The system under study basically operates under two conditions**,** namely the Ground Mobile and the Missile Launch conditions per MIL-HDBK-217F. The failure rate and the mean time to failure of the main computer of the missile launch system that is composed of several subsystems as shown in Table 1 is estimated based on MIL-HDBK-217F and the results are shown in Figures 2 and 3 below.

Table 1 Estimated failure rate and MTTF for the Main Computer under Ground Mobile and Missile Launch Conditions

| Subsystem Number | Name of subsystem | $\lambda_{GM}$ | $\lambda_{ML}$ | $MTTF_{GM}$ | $MTTF_{ML}$ |
|---|---|---|---|---|---|
| 1 | Main computer case | 47.74346 | 179.2709 | 20945.2771 | 5578.15016 |
| 2 | CPU Module | 54.108564 | 199.445936 | 1841.3628 | 5013.89008 |
| 3 | IO Module | 33.3053974 | 122.360265 | 30025.1634 | 8172.5877 |
| 4 | D/A Module | 59.7451833 | 257.339113 | 16737.751 | 3885.92309 |
| 5 | B01 Supply Module | 42.48922 | 194.2104 | 23535.3814 | 5149.05484 |
| 6 | B02 Supply Module | 29.47531 | 157.49976 | 33926.7 | 6349.21602 |
| 7 | Power Supply Module | 4.235 | 18.59 | 236127.509 | 53792.3615 |

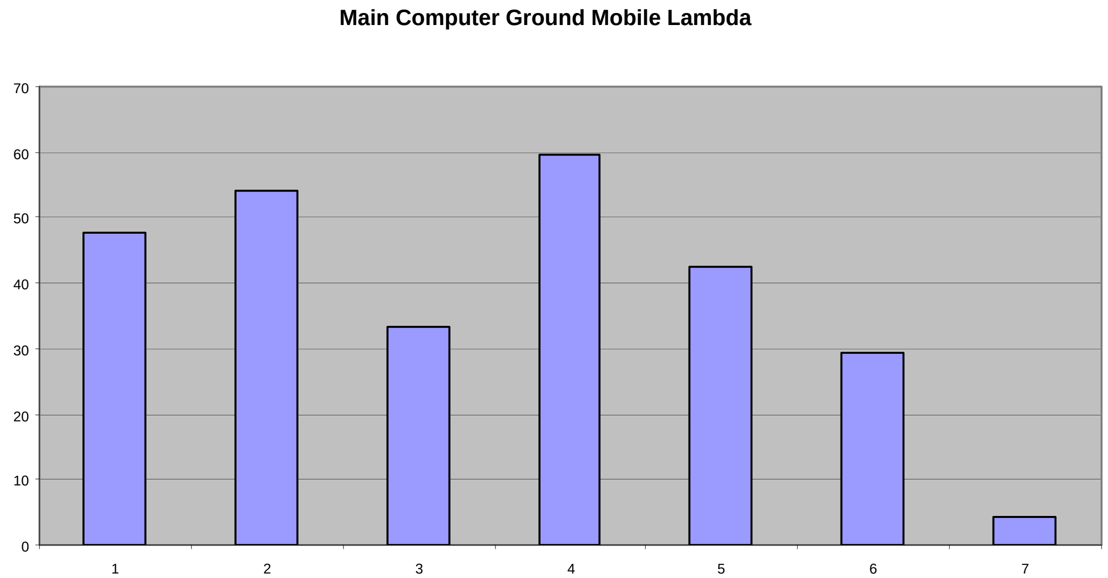


Fig 2 The estimated failure rate of each subsystem of the main computer under ground mobile conditions

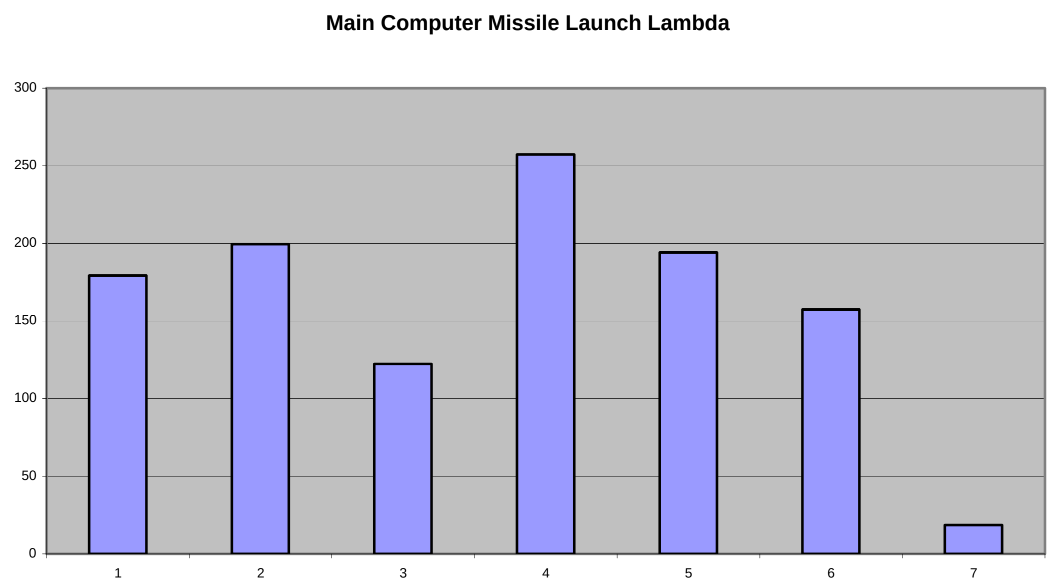


Fig 3 The estimated failure rate of each subsystem of the main computer under missile launch conditions

**3. The Availability of the Overall Coastal Missile Defence System**

The extensive sophistication and the mixture of technologies involved in a missile defence system make the analysis of its reliability extremely difficult. On the other hand, the deployment of systems with partially worn out parts, parts of a low quality, or parts with a potential intrinsic mode of failure is unavoidable. Since the failure of parts is of a stochastic nature and the exact time of need for the operation of the site is not predictable, it is vital to study ways to maintain a high level of availability for the defence system. High system availability coupled with preparedness of the forces who are supposed to deploy these systems is the key to successful operation of the mission of such systems.

The extensive war on our western borders for several years during the 1980s plus the many years of reconstruction in the post war years led to a drastic reduction of military spending and the reliability of the defence systems. Later on, with the increasing threats in the area more attention was paid to this sector.

The need to pay close attention to the reliability of the defence system is being felt more than ever before. This includes all aspects of planning, design, testing, manufacturing, maintenance and repair, and logistics.

Given that we have obtained the reliability measures for the main computer of the launcher, we may use the same procedure to obtain the reliability of the whole launcher. To study the availability of the overall coastal missile defence system, we must develop a simple model so as to avoid complex computations. If we assume that the availability of each of the six subsystems that exist at each missile site are equal to each other, say A, then the availability of the site will be equal to $A^6$. The availability of the overall missile defence system including n sites would be equal to $A^{6n}$. To show the importance of the availability of each subsystem on the availability of the overall missile defence system, the availability of the overall system is computed for systems assuming 5 and 10 subsystems. Of course, given the 2440 kilometes of coastal regions in the south and the fact that the typical range of such missiles is in the order of 100 to 150 kilometes, it is clear that more than 10 such sites are needed for full coastal coverage. It should be remembered that these systems have a slow mobility, and may be attacked once deployed. This fact indicates the need for even a larger number of such systems in the overall coastal defence system in the Persian Gulf region.

Table 2. The availability of the overall missile defence systems assuming various levels of availability for each of the subsystems at a given site

| Assumed number of sites in the overall coastal defence system | Availability of the overall system given that each subsystem has an availability of A=0.7 | Availability of the overall system given that each subsystem has an availability of A=0.8 | Availability of the overall system given that each subsystem has an availability of A=0.9 | Availability of the overall system given that each subsystem has an availability of A=0.99 |
|---|---|---|---|---|
| 1 | 0.118 | 0.262 | 0.53 | 0.942 |
| 5 | $2.29x10^{-5}$ | $1.235x10^{-3}$ | 0.042 | 0.742 |
| 10 | $5.23x10^{-10}$ | $1.524x10^{-6}$ | $1.479x10^{-3}$ | 0.55 |

Note that it is highly expensive to achieve very high availability rates for each subsystem at a given site. A review of the results shown in Table 2 indicates the importance of maintaining high availability for each subsystem at each site to provide for a reasonable level of availability for the overall coastal missile defence system. Reliability growth for the system may be achieved by improving the reliability of each subsystem. This is indicated by the results shown in Table 3 which show the percent reliability growth in the overall coastal defence system assuming that the availability of each subsystem is raised from 0.7 to the new values indicated in the first row of the Table.

Table 3 Percent growth in the reliability of the coastal defence system due to an increase in the availability of each subsystem form 0.7 to values indicated in row 1.

| Assumed number of sites in the missile defence system | $A_2 = 0.8$ | $A_2 = 0.9$ | $A_2 = 0.99$ |
|---|---|---|---|
| 1 | %122 | %349 | %698 |
| 5 | %5293 | %183306**%** | %3240074 |
| 10 | %2291295 | %334416726 | %1051625238 |

Of course, it is not so easy to raise the availability of each site. It requires a lot of investment, engineering work and reliability testing before any reliability growth may be achieved.

An integrated reliability program usually includes reliability testing programs that should be implemented such that all the reliability needs for the product are covered. The design of an optimal reliability testing program will also help reduce the overall life cycle costs of the product. The reliability of a system is affected by the reliability of its components and the way they are interconnected and manufactured. One may improve a product's reliability by using more reliable components of a higher quality or system redesign using high reliability parts from newer technologies.

Reliability growth can also be achieved by other means such as derating of parts (Radu, 2003), use of redundancy in design and proper design of accelerated life testing and environmental stress testing (Gatelani, 2007). To ensure that the systems deployed in the field have a high reliability, proper environmental stress screening programs must be designed and implemented (Yang, 1998).

## 4. Conclusions

Given the need to protect the integrity of the country against potential threats from the Persian Gulf and the Oman Sea regions, Iran needs a strong coastal missile defence system. Considering the typical range of shore to sea missiles considered in this study and the vast region under coverage, a lot of reliability improvement is needed to maintain an acceptable level of availability for the missile defence system.

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