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REVIEW PAPER

Quality and Reliability of Missile System

Prahlada

Defence Research & Development Laboratory, Hyderabad–500 058

ABSTRACT

Missile system is a single-shot weapon system which requires very high quality and reliability. Therefore, quality and reliability have to be built into the system from designing to testing and evaluation. In this paper, the technological challenges encountered during development of operational missile system and the factors considered to build quality and reliability through the design, manufacture, assembly, testing and by sharing the knowledge with other aerospace agencies, industries and institutions, etc. have been presented.

Keywords: Missile system, reliability, weapon system, test and evaluation, designing, assembly

1. INTRODUCTION

A missile system is an integrated product of multidisciplinary and multi-technology subsystems. The ultimate missile system is realised by knitting through common thread of quality and reliability, leading to the deployment of a robust weapon system. The missiles are unique aerospace systems required to perform with a high degree of reliability even after 10 years of storage. Figure 1 shows the challanges in operational missile system. If all the subsystems do not function effectively, efficiently and in unison, the missile system will not be effective and will not achieve the intended goal. It is the quality of design, manufacture, assembly, testing and evaluation that will determine the reliability with which the system will function as intended. Therefore, quality and reliability have to be built into the design, manufacture and assembly. The systems have to be designed for bulk production by a production agency and not only on its demonstration of performance. Hence, the designers have to design the systems individually and collectively, to deliver a high quality and high reliability product.

2. BUILDING QUALITY & RELIABILITY IN DESIGN

2.1 Building Quality in Design

Quality can be defined as the ability of the system to meet the stated or implied needs. In other words the system should function effectively for the entire duration, from launch to impact.

For a missile system, quality built-in during the design is of paramount importance because it is a single-shot system and hence, there is no scope for repair and reuse. Many of the subsystems inside are also single-shot in nature and hence do not lend themselves to any testing, prior to launch. Quality during design is mainly achieved through the use of sound engineering practices and extensive reference to standards for materials, processes and evaluation. In short, the design is for a product which has to survive in severe environment, after long duration of storage, and called upon to perform efficiently with a short preparation time. Therefore, the use of correct practices for design considering all the severities of the

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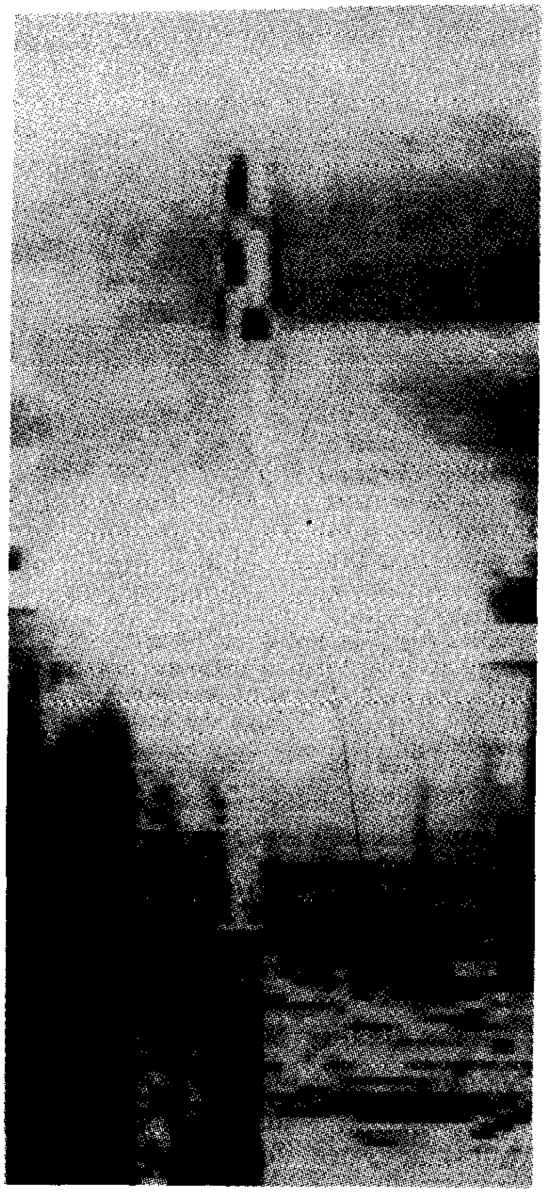

Figure 1. Challenges in operational missile systems

environment; choice of correct material, correct form, shape and structure; use of appropriate manufacturing process; application of mandatory post-process treatments; use of the recommended methods of handling and storage; and finally using the right tools and fixtures for assembly will ensure a high quality product.

In the initial stages during designing, developing, manufacturing, flight testing and transferring technologies to public sector undertakings (PSUs) and private sector, one has to face failures, learn from that experience and slowly move towards the

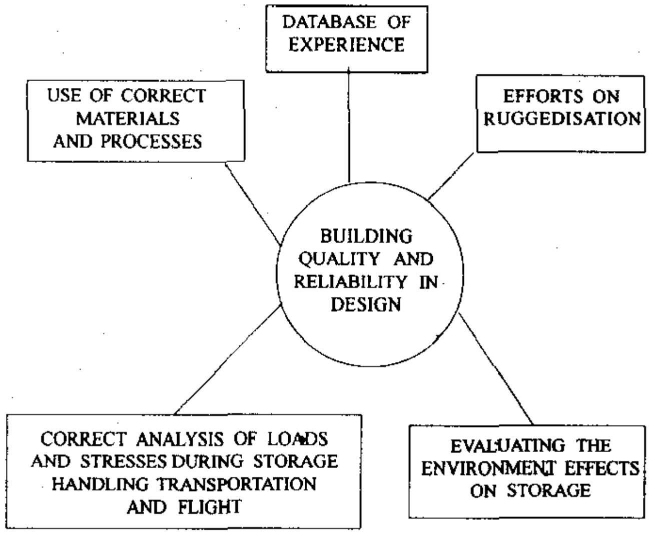

Figure 2. Building quality and reliability in design

objective. The experience makes one wiser and confident of doing right the first time and every time in the future endeavours (Fig. 2).

For designing a system, the kind of loads which the system has to encounter during its flight from launch to impact have to be correctly estimated. The loads could be due to propulsion, aerodynamics, vibration, shock and many other forcing functions due to various flight manoeuvres. It is essential for a good designer to know, evaluate and estimate these loads as accurately as possible. This could be achieved through modelling and simulation, through data available in the literature or more through experimentation. Today, computational fluid dynamics (CFD) techniques are well advanced to estimate the aerodynamic factors with fair accuracy, reducing the need for extensive experimentation or literature survey.

2.2 Reliability in Design

The fundamental definition of reliability is how well a system performs the intended functions for the required duration under given conditions. The margin of safety provided on these loads ultimately determines its reliability. If the data is scanty and inaccurate, higher safety margin is taken to cover up the ignorance. Though it may enhance reliability, it may render the system inefficient. Hence, an optimum balance or a suitable trade-off has to be achieved between reliability and system

Figure 3. A typical canisterised tactical missile system

effectiveness. This, once again, emphasises the need for accurate data on the loads, or stresses on the system to be designed, eg, propellant tank thickness is governed more by bending loads than internal pressure. Detailed failure mode effect and criticality analysis (FMECA) is carried out to eliminate the failure modes and make the design more robust.

3. TECHNOLOGICAL CHALLENGES

DRDO with a foreign partner is working on the development of advanced supersonic anti-ship missile system to compete in the world market. This missile system meets all the quality and reliability challenges of a typical canisterised tactical missile system (Fig. 3). Some of the technological challanges are:

- Missile ejection system
- Unfolding mechanisms for fins and wings
- Pressurisation systems
- Auxiliary propulsion units
- Nose cap separation
- Control and actuation system
- Front docking mechanism
- Variable throat mechanisms
- Terminal guidance.

The Indian industries will be producing these mechanisms and subsystems.

Assurance of quality and reliability of the unit must be addressed by the following organisational and technological activities:

(a) Using effective methods of diagnostics

(b) Standardising and unifying the technological processes

(c) Ensuring a single method and given accuracy of measurements

(d) Organising a system of inspection/testing

(e) Composing the list of specially critical operations and technological process sheets

(f) Organising a system of accounting and analysing the reasons for the failures

(g) Conducting the analysis of deviations from the design documentation

(h) Realising the activities for increasing the reliability

(i) Observing the acceptance standards for the manufactured items specified by the design documentation

(j) Introducing the initial prototype subjected to the stringent ground and flight testing (functional tests)

(k) Conducting copyright inspection on the manufacturing firm

(l) Probability of the failure-free passing of tests of the units at the manufacturing plant must be not less than 0.95.

(m) Probability of failure-free operation of the unit during the prelaunch preparation, launch and flight must not be less than 0.95.

(n) Probability of preserving the efficient condition of the unit during its continuous stay on the carrier up to three years must be not less than 0.90.

(o) Probability for preserving the efficient condition of the unit during its storage in operational organisations up to 10 years must not be less than 0.95.

4. RELIABILITY OF MISSILE DURING LONG STORAGE

Missiles have to function even after long storage with little or no maintenance. The system also needs to be protected from climatic conditions and mechanical factors during storage and transportation.(Fig. 4)

Special storage-cum-launch canister has been designed to meet the requirements such as

(a) High temperature (55 °C)

(b) Low temperature (–40 °C)

(c) Relative humidity (98%)

(d) Corrosion environment

(e) EMI/EMC shielding

(f) Mechanical factors (due to handling and transportation).

The composite canister plays a critical role during the storage as well as the operating phase of the missile system. During the storage, it protects the missile system and also enables its easy handling and transportation. It houses the gas generator to be used for ejecting the missile from the canister.

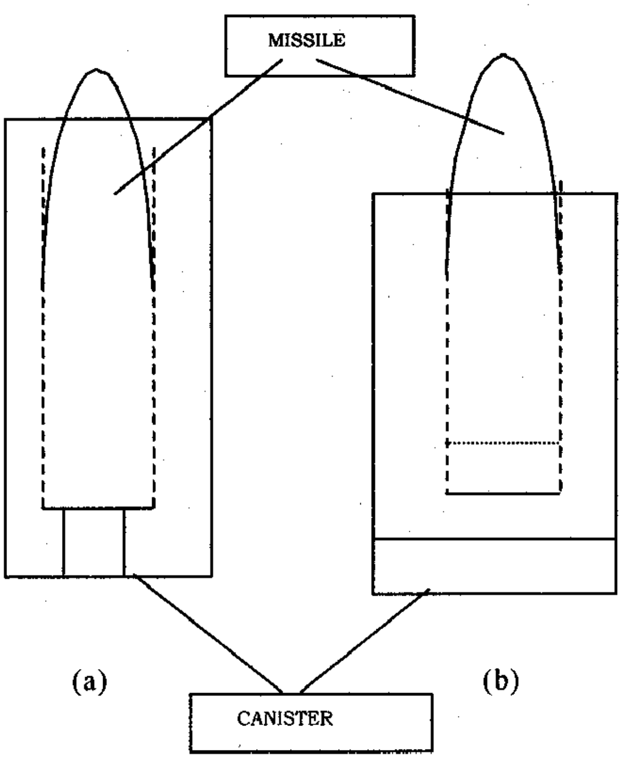

Figure 4. Reliability of missile during long storage, (a) before launch, and (b) after launch.

The composite canister assembly is tested for external and internal pressures and also cleared by non-destructive testing. Leak test is carried out to ensure non-ingress of moisture/gases. The hardware is qualified for all the loads by structure load testing. Stringent qualification and acceptance tests simulating the actual condition provides the required confidence.

5. PROVING QUALITY & RELIABILITY

Quality assurance test plans are generated to meet the specifications as per the design document. Functional tests are carried out on each hardware before integration. Design qualification is carried out through qualification tests. Leak test is carried out during integration of sections, at each stage, and once again, at fully integrated stage to ensure hermetisation of missile system.

Quality and reliability is proved by carrying out extensive testing, like functional testing, environmental testing, accelerated testing, and flight testing. Qualification and acceptance test plans are separately evolved to ensure the necessary level of reliability (Tables 1 and 2).

Table 1. Test plan for ensuring gas generator reliability

Type of test	Reliability with 90% confidence	Number of tests
Development		
a) Proof	0.6	6
b) Flight (Hardware)	0.8	8
Qualification	0.9	15
Demonstration	0.99	23
Total		52

Note: A) If any failure and reason known, rectify and complete
B) If reason not known, repeat all 52 tests

Table 2 A. Reliability of subsystems

Airframe and mechanisms	0.998
Thermal control system	0.9999
Propulsion stage (sustainer)	0.975
Gas generator	0.99
Pneumohydraulic system	0.995
Telemetry	0.99
Onboard equipment	0.988
Booster stage	0.995
During and after 3 yrs of storage	0.93 (in deployment)
	0.97 (in storage)
Nose cap	0.999
Thruster	0.99994
Internal nose cap	0.9998
Canister	0.999

Table 2 B. Reliability of subsystems–summary

Description	Prelaunch preparation launch & flight	In deployment on carrier (3 yrs continuous)	In storage (10 yrs)
Propulsion stage	0.957	0.91	0.95
Canister/launch system	0.9995	0.999	0.999
Missile	0.956	0.90	0.95

6. SHARING OF KNOWLEDGE

The Defence Research and Development Laboratory (DRDL), Hyderabad, in the last four decades, has built its strength by creating required infrastructure i.e., technical manpower, machinery and equipment, and technologies. Indian Space Research Organisation (ISRO) has also proven many frontal technologies in space areas. Knowledge sharing within the organisation as well as with other organisations will be highly beneficial to ensure that the aerospace systems will have the required reliability for such stringent applications (Fig. 5) Some of the areas where knowledge sharing takes place at the inter and intra-organisational levels are:

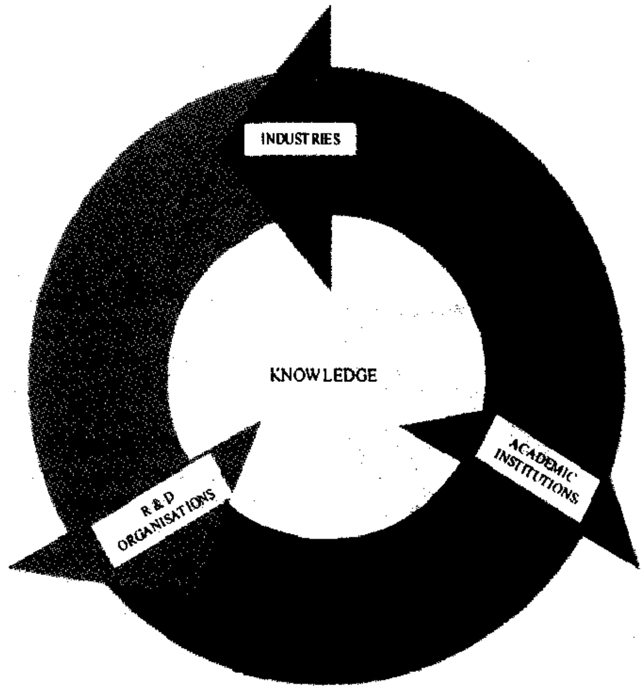

Figure 5. Sharing of knowledge

- Modelling, analysis and simulation
- Life prediction of soild rocket motors
- Quality and reliability database
- Testing equipment, facilities and techniques
- Inertial navigation and guidance system
- Filght instrumentation packages (PCM, Tx, transponder, sensors)
- PYRO mechanisms
- Control actuation system
- Materials and processes.