

Engineering and Innovation in Manufacturing and Production of Akash Missile System
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1. INTRODUCTION

- 1.1 Akash Mobile Air Defence Weapon System has been designed for defending and protecting the Vulnerable Areas (VAs) / Vulnerable Points (VPs) from aerial targets penetrating from low, medium and high altitudes. The system developed by DRDO has completed all development flight tests, user trials and transfer of technology for production.
- 1.2 This paper brings out various engineering issues / problems that were faced in producing the first indigenous surface to air missile system in the country and how successfully these issues were resolved, how industry got benefited and production targets are being met.

2. ENGINEERING IMPROVEMENTS AND INNOVATION IN AKASH WEAPON SYSTEM DURING PRODUCTION

- 2.1 During the development, certain functional as well as operational features were identified for improvement by the users over and above what are indicated in ASR / GSQR. The preparation time of missile has to be minimized number of vehicles to be reduced, thus reducing manpower and time for preparation and operation. The improvements carried out in production version equipment and their benefits are indicated in subsequent paras. These modifications have already been verified through user operated validation flight trials in May 2012 on production version equipments. The general production engineering measures such as improving ergonomics, miniaturization by adapting latest technology hardware being common to all subsystems, they are not discussed here. Only some of the innovative engineering and managerial solutions have been brought out.

2.2. IMPROVEMENTS IMPLEMENTED IN THE COMMAND CONTROL CENTRE AFTER USER TRIALS OF JUNE 2007

- a) **Inter-visibility computation to aid deployment:** Provision has been built in command control center to compute Line of Sight inter-visibility between any two stations given the latitudes and longitudes. This aids the commander in deciding the location for the deployment in order to achieve radio communication between them at the earliest. This has been achieved with the help of available digital terrain map.
- b) **Automatic Bias estimation and correction:** Provision has been made to estimate the bias offset of the reporting radars. This has been achieved by providing for the selection of one of the radar as reference radar and correcting all others with respect to that.
- c) **Manual backup for Multi-Sensor Data Fusion (MADF):** Control Center contains a proven, state of the art, automatic multi sensor data fusion software for accurately

synthesizing the real air situation picture. But under unforeseen conditions where data of any radar cannot be automatically correlated, manual intervention has been provided for association and disassociation with which the operator can provide information to the system for foolproof data fusion.

- d) **Clutter zones processing:** Provision to control false tracks has been made by creating zones in control center where no automatic tracks will be created.
- e) **Integration with Higher Echelons:** Work is at an advanced stage of realization to integrate control center with Integrated Air Command and Control System (IACCS) of the Indian Air Force for exchange of track data and control information. Control information includes the Rules of Engagement, automatic query for identification and response and clearance to engage.

2.3 IMPROVEMENTS IN FLIGHT LEVEL RADAR

Programmable Signal Processor

Upgradation to programmable Signal Processor, using of SHARC processors employing Digital Fourier Transform (DFT) has resulted in having greater flexibility for fine tuning certain ECCM features and facility for future improvements without hardware changes. Radar Signal Processing in Coherent mode, has resulted in improved sensitivity (Minimum Detectable Signal) and Doppler filtering.

a) **Digital Radar Scan converter as replacement of Analog CRT display**

The analog display of the radar has been replaced with a Radar Scan Converter (RSC), which uses a touch panel and a 21" LCD interface for creating and viewing of targets in real time.

b) **Automatic PRF Selection Algorithm for ensuring high reliability of tracking**

A new algorithm for PRF (Pulse-repetition frequency) selection based on velocity estimates of the targets has been implemented.

c) **New tracker algorithm for improved accuracy for 'High-g' maneuvering targets**

Upgradation of tracker with the incorporation of "Interactive Multiple Model" for tracking has been completed. This feature has also been validated with sorties of "High-g" maneuvering targets during the June 2009 trials.

d) **Modular and Compact receiver**

Receiver Mark II has been configured as a modular and compact solution for low power microwave subsystem requirements. The newly configured Rx has achieved reduction of about 50% in bulk, besides the improved reliability.

e) **New algorithms for weapon control and automation**

The decision support software, namely, Weapon Control Computer (WCC), which is a part of the FCC computer subsystems, has been upgraded with new Launcher Selection Algorithms. This has improved the reaction time significantly due to reduced human interaction. Human Machine Interface (HMI) for the Radar Computer has also been developed which enables remote operation of the radar.

f) Highly secure operating system based on Linux for display system of Control Center

The erstwhile operating system on Microsoft Windows suffered from the drawback of its susceptibility to virus attacks. The Linux operating system is more secure and robust.

g) Replacement of TWT (x-band Command Link transmitter) with Indigenous Microwave Power Module (MPM)

- i) The imported X-band TWT based transmitter was weighing 100 kgs. It used to consume 12 KVA with volume of 22 ltrs and was costing Rs. 40 lakhs.
- ii) The indigenously developed MPM (Microwave Power Module) based Transmitter weighs only 12 kgs., consumes 5 KVA power, occupies 4.5 ltrs and costs only Rs. 12 lakhs.
- iii) The new indigenous MPM provides for greater compactness, higher stability and increased reliability. Moreover, due to its compact design it has been mounted on the rear side of phased array antenna itself.

2.4 INOVATIONS IN PRODUCTION OF PHASED ARRAY ANTENNA

2.4.1 Pick-up and Radiating Plates : Initially it had taken 6 months to machine one set of pick-up and radiating plates. The following improvements were done:

- a) Formule 62 stress relieving machine was used for in process stress relieving during machining of the plates. Tooling was developed for clamping the plates during stress relieving.
- b) The total process of manufacturing of these plates has been optimized to the extent that one set of plates is now made in one month.
- c) Inspection of the plates is carried out on the machine itself and the clamping of plates on the machine is done using the same holes with which the pickup and radiating plates are clamped in the actual array (hence simulating the actual condition)

2.4.2 Array PCBs : The initial PCBs were made through Micropack Bangalore. Since the size of the machine on which the holes were drilled (for PCMs location) was not big enough the requisite tolerances were not met and a lot of re-work was required to be done in the assembly stage. A vendor was found in Ahmednagar with the requisite size of the machine and the PCBs are now manufactured through them meeting the required tolerances. The vendor was developed by BEL to meet the overall requirements.

2.4.3 Continuity checks on PCBs : There are four pins in each PCMs (Phase Control Modules) which take location in the PCB. Hence there are about 4300x4 (17200) connection. Continuity checks have to be performed to confirm correctness of all these connections. Special jigs have been made to reduce the total cycle time of checking these connections.

2.4.4 Slow Cycling of Array: To remove the infant mortality in the PCMs the array is subjected to multiple cycles of high power testing (for varying duration). After each cycle of full power, each PCM is checked for performance. Hence after every cycle all 4300 PCMs are to be checked for performance. Initially it was all done manually and hence the time taken for each cycle was more than two days. However now automated test set up is being designed to bring down the cycle time. Also multiple tools have been made so that this activity can be simultaneously performed in multiple arrays hence bringing down the overall time cycle.

2.4.5 **NFTR testing** : characterization of first array in NFTR took six months. The following changes were brought about to reduce the cycle time:

- a) Initially the array was tested without radome (since no reference surface was available when radome was put in the front side of the array). Hence tests had to be repeated with Radome. However now the testing is done with the radome and four machined plates are put at the four edges of the radome. Hence the cycle time got reduced.
- b) The application software for collimation was optimized to reduce the total iterations required for collimation of the array.
- c) It is proposed to upgrade the NFTR facility. In this upgrade instead of one probe there would be an array of probes which would substantially bring down the overall testing time of the array. It is envisaged that after hybrid upgrade the total cycle time for testing of the array at NFTR would become about two weeks.

2.4.6 **Transportation of Array from BEL-GAD to Bangalore**: Special fixture has been designed which simulates the actual container top on which the FLR/TLR antennas are mounted. The Antennas after customer clearance at BEL-GAD are transported to Bangalore on these fixtures. The fixture has four ISO corners and can be bolted on to standard trucks/trailers having ISO corners for clamping of standard containers. Multiple fixtures have been made so that simultaneously multiple antennas can be transported to Bangalore.

2.5 **IMPROVEMENTS IN THE AKASH LAUNCHER SYSTEM**

a) **Improved Operation and Maintenance features**

- i) Provision of identical motors and drive for Azimuth. Elevation and outriggers to achieve standardization and better maintainability.
- ii) Provision of the entry of three Taboo zones, both in azimuth and elevation for manual mode of operation in order to avoid inadequate slew of launcher to the restricted zones.
- iii) Improved layout of mechanical subsystems and electronic module on launcher to get easy access for maintenance and replacement.

b) **Human Machine Interface (HMI)**

- i) Provision of Standby local console to give redundancy in operation.
- ii) Provision for Health monitoring of subsystems remotely from BCC.
- iv) Enhanced security against unauthorized operation of the equipment through the provision of Software Access control for the operator's console.

c) **Power Supply System**

- i) Provision for automatic switching over to the alternate power supply source to enable uninterrupted operation of the launcher. The choice of power supply is automatically made from among various sources such as DG set main, DG set standby, commercial power supply or batteries.
- ii) Provision for silent operation by using battery bank.

- iii) Battery Monitoring Unit (BMU) to be provided for continuous online health monitoring of each battery in battery bank.

d) Transportation

- i) The minimum ground clearance of Launcher has been increased to 400 mm for 300 mm without adversely affecting the feasibility of transportation by air, rail and road.
- ii) Provision of two different canopies for transportation of launcher without missiles and with missile.

2.6 MISSILE HARDWARE IMPROVEMENTS

2.6.1 Hardware changes

a) Sensor Package Unit

The Sensor Package Unit has been changed from free gyro based system to Roll rate based system. This change has been carried out as technology upgrade as free gyro based systems have become obsolete. Fibre optic based sensor package has been indigenously developed and flight tested. Production process for this unit is also established. About Rs. 12.0 lakhs of foreign exchange has been saved per item and the dependency has been reduced. The weight of this unit was reduced from 3.2 kgs to 2.5 kgs.

b) Pilot tube

The pilot tube has been removed from the configuration. The dynamic pressure calculation is being done onboard using sensor package unit and ground based commands using radar estimates of height and velocity. This provides enhanced reliability and improved aerodynamics of missile by reducing its weight and drag.

c) Wings & Fins

The wing and fins with reduced hinge moment have been designed in order to improve the maneuverability and controllability of the missile.

d) Delivery of “Ready to Fire” Missile

The following changes have been carried out in order to provide ready to fire missile to the user :-

- i) The Pyro Relay Unit has been modified to provide extra safety for ground fired pyros. With this the pyros will be fitted in the factory itself, thereby providing improved safety and no preparation in the field.
- ii) The Air Bottle is charged in the factory itself and need not be charged in the field.
- iii) Wings and Fins need not be removed during transportation. The container has been modified to carry the missile with wings and fins duly assembled.

e) Improved reliability of Command Guidance Unit

The Bias-T unit which was outside the CGU has been integrated in the system itself to provide improved reliability.

f) Additional safety during checks

The firing pulse from radio proximity fuse to SAM which was earlier going directly has been routed through a relay to provide improved safety during the checks.

g) Thrust on Indigenization

The subsystems which were earlier imported are being indigenized in order to reduce foreign dependency.

i) Thermal battery has been indigenized which was earlier imported.

ii) The imported connectors like Umbilical connector, push pull connector have been indigenized.

h) Improved shelf life of missile

The Section – III Airframe has been changed from Magnesium alloy to Aluminum alloy to provide better corrosion resistance and hence improved shelf life.

2.6.2 a) Improved Command Destruct Logic

The software has been modified to carryout command destruct based on a new logic for initiating maneuver after the cross over. Accordingly the warhead is exploded at a safe height. The change has been successfully carried out and validated as per the requirement projected by Indian AF.

b) Improved Reaction Time at launch

The Auto launch time has been reduced to 3 sec from 5 sec in order to provide better reaction time for the Akash Weapon System.

2.7. MANAGEMENT POLICIES ADOPTED

2.7.1 Quality management methodology through production phase

Since for the first time Quality assurance of such a complex multi discipline engineering work is attempted in the country, there was a requirement of ensuring water tight procedures. Considering this requirement, Master Quality assurance documents were created to indicate the policies for inspection and acceptance of items at module level, subsystem level, system level and weapon system level. This document also consists of the inspection and procedure to be followed for variety of equipments and their environment test requirements. The responsibilities of each stake holder (BEL, BDL, Manufacturing agencies, DRDO, Service agencies etc) were listed and stages were defined. Constitution of number of Boards like local waiver boards, standard design review boards, failure analysis boards, configuration control boards were defined to bring in clarity to production and inspection procedures. The QA responsibilities were distributed to the agencies spread across the country.

3.0 ISSUES RESOLVED DURING PRODUCTION OF AKASH MISSILE SYSTEM

Though it is meticulously planned to have a smooth production, there happens to be a requirement associated with the increasing rate of production, quality, reliability, new environment, re-engineering, validation of performance of production equipments etc. Some of the issues addressed during production are listed as follows:

1. Flow forming of managing steel rocket motor casings instead of roll bending.
2. Paintings, surface preparation
3. Plating of En 24 components, Magnesium alloy casings
4. ESS on all electronic packages
5. Sealing and rain proofing of missile
6. EMI/EMC testing of Missile
7. Corrosion of studs – (pitting / white marks)
8. Air intake bent tubes - Indigenization
9. Reconfiguration on trailers
10. Pre-flight-validation of modifications
11. Infrastructure establishment for missile storage / preparation buildings
12. Stage inspection clauses and testing classes
13. Weapon System integration documents
14. Phase-I, II trials of Weapon System
15. Validation flight testing of first batch production equipment (trials by IAF)
16. Vetting of all QA plans, BOMs, TS, ATP
17. Amendments through SDRCs/Acceptance of deviations through Waiver boards
18. Batch qualification testing of propulsion systems
19. Modified missile containers
20. New missile check out facility
21. Configuration finalization for Army equipment on Tatra with Rail transportability
22. Roadability trials
23. Second vendor development for Fuel Rich Grains (FRG)
24. Inspection constraints of MSQAA – contract engineers quality/delay
25. SOP to prevent Damage of missile container during transportation

26. Air bottle – monopoly issue – new manufacturers – alternate vendor qualification
27. Alternate to Tatra chassis – re-engineering requirement
28. ‘O’ rings/gaskets – Rubber components – additional vendors-aging qualification tests
29. Revised sampling plan, batch qualification plans based on production stability
30. Widening tolerances on drawings after studying manufacturing spreads over 50 sets
31. Weapons System integration site – Joint Investment by production agencies
32. Proper storage of Items/Electronic units after receipt storage at Lead production agency
33. Micro-porosity issues of booster grains from Ordnance factory
34. Divergent nozzle – process improvements

4.0 CONCLUSION

Engineering and production challenges faced for serial production of this sophisticated missile system have been indicated in detail. The innovations, improvements undertaken for various weapon system elements were indicated explicitly with the benefits obtained. Various issues that were encountered and resolved during production have been explained. The complete set of Indian industry (large scale medium scale and small scale industries) would be busy on production; product development and lifetime product support for the next 3 decades till the system gets phased out.

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