



## PRODUCT LIFECYCLE MANAGEMENT (PLM) IMPLEMENTATION FOR THE AIRBORNE EARLY WARNING AND CONTROL (AEW AND C) PROGRAMME

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### ABSTRACT

The Programme Office (PO), Centre for Airborne Systems (CABS), Defence Research and Development Organization (DRDO) is tasked with the development of the Airborne Early Warning and Control (AEW and C) System for the Indian Air Force (IAF). Being a large System-of-System Product, not only do the inherent product complexities through controlled and traceable product development environment pose numerous challenges but the requirement of spearheading and managing the co-operation between the Work-Centres (WCs) spread out across India is difficult. At the very onset, the PO recognized the need to adopt and deploy a suite of State-of-the-Art Hardware and Software that would focus on leveraging the AEW and C Programme information to deliver the system within time, cost and quality envisaged. The paper brings out how the PO effectively faced the numerous challenges at both the Product and Programme level through use of the Product Lifecycle Management (PLM) Technology.

**Keywords:** product lifecycle management, PLM, programme management, engineering product data management, force multiplier technology, AEW and C, change management, multi-site collaboration, requirement management, document management.

### INTRODUCTION AND OVERVIEW

The Programme Office (PO), of the Centre for Airborne Systems (CABS) under the Defence Research and Development Organization (DRDO) has been entrusted with formulating, controlling, monitoring, managing, integrating, flight testing and delivering the Airborne Early Warning and Control (AEW and C) aircraft to the Indian Air Force (IAF) adhering to the specifications formulated jointly by IAF and DRDO. During the AEW and C development, the PO is required to interact, interface, monitor all activities farmed out to the various Workcentres (WCs), each of which is responsible for some part of the product's planning, component preparation or assembly.

For the AEW and C Programme Development to be within the strict time schedules, every participant in the PO and outside it needs to have the latest information on the subject pertaining to them. The Product Life Cycle Management (PLM) solution was proposed for sharing product information across functions and teams so as to not only provide right information at the right time and place but also allow the programme team members within the PO and outside in the WCs to communicate and collaborate with each other on real time basis. PLM as conceptualized for the AEW and C programme has been implemented as a new way to think about product information through a System Engineering and Programme Management Perspective for execution of the programme within the time and cost constraints, meeting all of user specified requirements.

### OBJECTIVE OF THE PLM SOLUTION PROPOSED FOR THE AEW AND C PROGRAMME

The design, development, integration, testing and certification of the AEW and C system involve numerous

partners that are geographically distributed. Need was felt to pull together interrelated and interdependent information and disparate applications into coherent processes and consolidate all the AEW and C Programme information and processes into a common system. It was felt necessary to provide a Collaborative Environment through deployment of state-of-the-art technologies both in Hardware and Software for managing the complex AEW and C Programme Environment thereby enabling project teams to use tools, processes and methods that are unified under a heterogeneous environment.

As the AEW and C combats threats to the nation through early detection of enemy targets, it was required to have a solution that would combat threats to the programme (time, cost, scope) through early detection for better resolution of anomalies.

The Objective of the PLM solution implemented for AEW and C Programme at CABS was to progress the quality of data, have better control over the product data and improve internal and external communication during the complete lifecycle of development. This was essentially towards reducing complexity of Product Data and Management along with effective collaboration with the WCs.

The PLM solution proposed was thus about managing all of the AEW and C Programme information in an integrated and secure manner right from voice-of-customer namely the IAF requirement specifications to the final customer experience with the AEW and C System deployed within the services. The PLM solution proposed was about taking a 'Systems Approach' with respect to the information generated to support faster and more informed decision-making throughout the programme lifecycle.

At the very beginning a decision was taken that the system so implemented should have the ability to



capture data in a holistic manner with respect to the technology, processes and people across the organization as well as the WCs working for the AEW and C Development. The software should enable an organized process for creation, updating, storage backup, archival, access control and retrieval of all data related with the AEW and C product and programme/ project. It should ensure the management and control of configuration for design data as well as to control the flow of work within and across work groups and WCs in respect of product/ project data of the organization. It should also enable in controlling processes and ensuring regulatory compliances.

It was felt that the solution should also automate the review process, approval processes and data release processes. It should have document management and control functionalities built in to support all documentations of the organization including various types of design data such as drawings, 3D models, analysis, software outputs, in-house software, text documents etc. Data validation procedures to ensure consistency and correctness of data must be ensured.

The PLM solution should provide a complete enterprise solution for all its present and future endeavors in the development of the AEW and C Programme. The PLM Solution implementation at CABS has therefore taken a complete and holistic 'System Engineering and Programme Management Perspective' towards implementation.

## MANAGEMENT AND IMPLEMENTATION METHODOLOGY

Implementation was taken up through the 'Systems Integrator (SI)' approach in which, it was decided to evaluate vendors at three levels. At the first level was the evaluation of the offered product and its ability to meet the requirements, at the second the capability and experience of the vendor to act as a 'System Integrator (SI)' in customizing and integrating the chosen product towards meeting the requirements of each of the solution areas. The third level consisted of the vendor's capability to supply and deploy the hardware required for the architected solution. The SI was also evaluated towards ensuring that the complete PLM solution includes:

- Highly integral technology
- Ability to enhance the creation and management of AEW and C related information and processes
- Establishing and maintaining a smooth integrated development process that spans across all the cross-functions and WCs
- Delivering the most appropriate Functionality
- Best practice processes
- Means to tightly manage them
- A Conductive incremental approach to implementation

## PHASES OF IMPLEMENTATION

Some of the statements spelt out in the objectives are bold statements as is the case in the description of PLM

proposed by the industry press, research firms, various authors etc. The AEW and C development involves enormous, varied and complex technical and non-technical information that is to be generated at every stage of development pertaining to compliance to technical specification of components, systems, sub-systems, integrated system, software, hardware, Independent Verification and Validation (IV and V), platform support, performance, weight, quality assurance, programme schedule, material management, financial management, flight test schedule, airworthiness of systems, logistics, delivery etc to just name a few. The information was to be defined and organized so as to be available to the right person at the right place and time. The challenges to make such prodigious information available across the various stakeholders, across different WCs throughout the lifecycle of the AEW and C programme were plenty. Marrying such interrelated and interdependent information in time is also difficult to say the least. As this was a pioneering effort being taken up at such a scale, it was felt that in order to reduce the risks undertaken in such implementations, it would be necessary to go in for a 'conductive to incremental' approach to implementation. In the first phase it was decided to implement the key solution areas of:

- Multi-site Collaboration with DRDO Work-Centre
- Programme Management
- Document Management
- Requirement and High Level Design Management
- Engineering Product Data Management (EPDM)
- Configuration and Change Management
- Integration with the Finance and Procurement Management Software

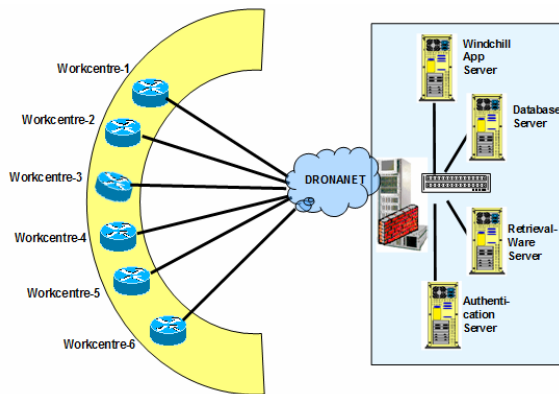
## MULTISITE COLLABORATION WITH DRDO WORKCENTRES

The AEW and C System is a 'System of Systems' Programme that requires the use of Core competencies of several establishments geographically distributed. Keeping in view that management of an extensive and scattered network of workcentres, subcontractors and partners is not easy and requires Effective Data Management. It was thus imperative that an Advanced Collaborative Environment be created amongst all the stakeholders. In the ideal scenario PLM integrates all stakeholders involved in the product during its entire lifecycle be they be - users, vendors, manufactures, partners, production units etc. PLM is a powerful tool that utilizes advanced communication and technologies to speed up communication by creating a collaborative extranet environment through which data is instantly available as it is needed across all the identified players. It was well appreciated at the very beginning that Connectivity and Collaboration carried out as such could have a major, positive impact in reducing the timelines for the AEW and C Programme. However, due to the inherent security requirements along with mitigating the risks in



implementation, it was decided at the highest levels within DRDO to first prove the concept connecting the PO with the DRDO WCs directly involved in the AEW and C development and spread out across India. DRDO's Rapid On-line Network Access (DRONA), initially a secured 2Mbps leased line circuit (which was later enhanced) was used for connectivity with necessary firewall configurations. The users at the WCs were verified through the Lightweight Directory Access Protocol (LDAP) enterprise directory setup at the PO and were provided with integrated user id's and Password for accessing the system. Facility for an integrated solution towards receiving e-mail notifications was also implemented. A single Sign-on facility was created for all users for all software integrated with the PLM Solution.

It was decided at the very beginning that the PLM solution should be able to provide end-users at WCs all functionality through the web interface for all solution areas in the system on a need-to-know basis. The web-centric environment would be such that the users at both the PO and its WCs would have the ability to share, access, collaborate, control, integrate and view the management information, product information and technical data using nothing more than a web-browser. Figure-1 shows the synergistic network diagram of PO-WC connectivity through the DRONANET of the DRDO.



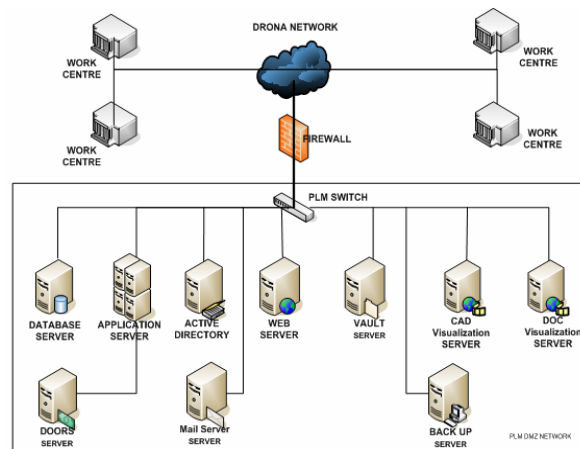
**Figure-1.** Network diagram of PO-WC connectivity.

Figure-2 shows the configuration of the PLM Demilitarized Zone (DMZ) network. PLM DMZ setup describes the configuration of various PLM servers and the network connectivity. The PLM servers are arranged in a DMZ and connected to the DRONA Network through a Firewall. The various security levels that are implemented are as follows:

**DRONA firewall:** The Firewall restricts the unauthorized intrusion from other WCs to the PLM network servers.

**SSL:** Secured Sockets Layer Connection (SSL), which is encrypted and ensures reasonable protection from eavesdroppers and man-in-the-middle attacks.

**ADS:** Active Directory Service (ADS) allows only the registered users to access the PLM application.



**Figure-2.** Configuration of PLM demilitarized zone.

## DOCUMENT MANAGEMENT

In most projects, a substantial amount of productivity of Scientists is lost for the lack of efficient and easy retrieval of documents. Effective information retrieval and filing methods with document management and control features go a long way in helping scientist concentrate on their core competencies. This solution area targeted at identifying, managing, accessing and re-use of all of the documents pertaining to the AEW and C life cycle by supporting a complete set of authoring tools for revision control with check-in/ check-out features and work flow capabilities, search and retrieve features etc. Document types across the organization and the AEW and C Lifecycle were identified and attributes specified for the same. Workflows for notification, tracking and alert mechanism and ability for electronic approval of documents and advancing to next stage were also made available to the Scientist. Integration with applications that provide live viewing/editing through regular day-to-day office applications was made possible. The software deployed had information retrieval and filing methods with document management and control features and publishing which were inherently powerful. Surprisingly, Version and iteration tracking to record the history of documents and editing controls built in within the Product and Project Module of the PLM Product itself differed which then required to be looked into for further customization.

## REQUIREMENT AND HIGHLEVEL DESIGN MANAGEMENT

At the onset of the AEW and C Programme Sanction, the Systems Engineering (SE) Group within the organization had narrowed down on the selection of 'DOORS' as the software for the Requirement and High Level Design Management. The functional requirements were to be expanded into the design requirements that would identify and define the functional and physical



configuration of the AEW and C Product and its Sub-product/ systems. The PLM tools necessarily required to integrate with this software. Numerous discussions were had with the various PLM Vendors on this aspect and surveys carried out to see if any such previous integration was carried out globally. A white paper on one such integration carried out globally was studied in detail where the PLM environment was used to link and search the requirements existing in the DOORS environment by designers who required details to construct, operate and maintain their respective end product(s). This methodology was followed for the AEW and C development also and Attribute mapping between the DOORS and PLM environment was carried out through customization.

### PROGRAMME MANAGEMENT

The challenges posed in management of large scale R and D projects involving Force Multiplier Technologies (FMT) are very different from conventional management and require different concepts and techniques. The challenges posed are immense and varied. Such projects are highly prone to cost and time over-runs. Therefore, it is very essential to plan and control the activities. Ironically, in an R and D organization planning of activities is fraught with shortcomings. The problems of taking an aircraft or weapons system from early research through technical development, design and manufacture are laden with complexity, uncertainties and difficulties. This is particularly so when working on the frontiers of technology. Added to this, was in this particular case the management of WCs, which in itself is not easy. Plans across are continuously updated due to 'Moving targets', changing requirements, depth of knowledge gained as one progresses in the project etc.

This solution area posed immense challenges and also required sufficient amount of customization to be carried out towards meeting the requirements. In the area of Project monitoring and tracking, the planning and execution was done keeping in mind the strengths and weaknesses of MS-Project and the Project Module in PLM. The strengths of MS-project features in planning were combined with the strengths of the Project Module features of Collaboration and Execution in the PLM Software. These two were used in tandem to complement each other. Base lining features as they were not readily available in PLM Project Module were also customized within the PLM Project Module towards providing features for comparisons of plans as they moved and changed along, in time. Though the Project Module in PLM provided for real time status description of actions assigned to Scientists, the existing features did not allow for maintaining the history of updating the status descriptions which was required as and when WCs were reporting their progress to the PO. Customization was therefore carried out to maintain this history. Major effort was put towards customization of meetings in the system so as to correspond to the reality of the reviews conducted. The Project Module in PLM provided a rather simplistic

view of meetings which treated each meeting as an entity in it. The linking of data across various meetings such as action items, the capture of decisions, recommendations, standing instructions, approvals and sanctions etc. and linking of action items to its relevant project was not inherently possible through active retrieval. Inability to view the holistic picture in graphical form and the 'domino effect' of delays of sub-projects being carried out at the WCs on the overall programme being coordinated by the PO was a major constraint which was also addressed for customization.

### ENGINEERING AND PRODUCT DATA MANAGEMENT (EPDM)

This solution area essentially allows capturing of the engineering data and making it available to the entire enterprise based on access control mechanisms built-in during the entirety of the AEW and C Programme. It allows engineering teams to synchronize design data, share design models in workflow-driven processes, and collaborate across a fully digital environment. Objective was essentially to accelerate the product release cycle time, increase engineering efficiency and improve product innovation. Weight and Power are limited by the constraints proposed by the platform chosen for the AEW and C development hence the critical factors during the design and development to be considered are the weight and power requirements of each of the components that go into the AEW and C System. It is pertinent therefore that the changes in weight and power over the AEW and C lifecycle be monitored, tracked, controlled, accounted for at all times at all levels. As this was at the time not available Out-Of-The-Box (OOTB), Customization was carried out for displaying the roll-up of Total Target Weight, Total Actual Weight and Total Design Weight from CAD 3D models at individual component and assembly levels which roll-up to the sub-system and ultimately the AEW and C System level. The solution area EPDM also allowed for the visualization, communication and collaboration between WCs and the PO on Engineering Data, Automatic Product Structure and Bill of Material (BOM) generation along with engineering data accessibility through web-browser through secure need-to-know access controls.

Through this solution area, it was possible to bring in consistency of engineering data, provide history and comparison of all modifications carried out, storage of engineering data at common location was made possible and thereby possibility of efficient management of engineering data made a reality.

### CONFIGURATION AND CHANGE MANAGEMENT

Right from the word go, it was well known that in the development process of the AEW and C, Change will be inherent. While a change proceeds through a change process, the change process itself was required to be managed and controlled. This involved ensuring decision criteria is collected, due diligence is executed, and changes are routed accordingly. A common misconception is that



any change management system is bureaucratic and hinders the ability to react quickly to changes. However, a good change management system in place facilitates change, meaning the organization is more responsive to change. When the change process is executed with the documents, forms, steps and participants, a fully-traceable history of the decisions, planning, and implementation of change is captured. The OOTB change management workflows compliant with the CMII model developed by the Institute for Configuration Management (ICM) as industry recognized best practices were tailored so as to be consistent with the Configuration and Change Management Methodology followed for the 'AEW and C Programme'.

### **INTEGRATION WITH FINANCE AND PROCUREMENT MANAGEMENT SOFTWARE**

Due to non-availability at the time of Finance and Procurement Management Software for integration with the PLM System, it was decided to develop the Finance and Budget Module integrated within the PLM Solution only for the AEW and C Programme related information. Partial Procurement information is also captured in the customized module for display of reports and information in dashboards. The deviations in forecasts and actual spending can be planned, tracked and monitored on a need-to-know basis. Snap-shots through dashboards have been made available through which one can drill down to get further details if so required based on the user privileges and access controls provided. Currently more than sixty types of reports are accessible within the PLM System for view at different levels on a need-to-know basis as per their rights and privileges.

### **EDUCATION AND TRAINING**

Education and training, creating instructions and support material play a vital role as awareness; a pre-requisite for change is an important ingredient in the success of any PLM implementation undertaken. PLM requires changes in people's ways of thinking and working habits. This is a continuous endeavor as Cultural and Organizational issues arising from these cannot be under played and need to be looked at seriously. Training and Help Desk Functions at both PO and its WCs continue to play a crucial role in bringing about the change through regular awareness creation. Training needs at different levels are also regularly addressed.

### **AEW AND C PLM SOFTWARE LICENSES**

The companies offered either 'Enabled user' or 'Named user' licensing policy with the requirement of periodic audit jointly with the vendor company to assess the actual number of licenses used during the period. As this would not be in the interest of the government, the best advantage was to consider if the licenses being procured can be used for a maximum of 24 hours/day. Accordingly a formula was worked out which would give the actual user hours for which the software has been used by all users in excess of the user hours accounted had all

the number of licenses procured used the software for 24 hours a day on all working days during the year. Though the vendors were initially reluctant to accept this, acceptance of the proposed formula was made a pre-condition before their offers could be considered as this was the closest in meeting the 'concurrent floating' licensing policy as per the specifications. It was also impressed upon the vendors that the licenses would necessarily be perpetual licenses and the price quoted for additional licenses that may have to be regularized in the near future should be valid for a period of three years after the warranty period. Separate licensing for database applications in the background was also addressed.

### **RISK ANALYSIS AND MITIGATION STRATEGIES**

It was very important to carry out Risk Analysis in respect to going for a single integral development environment as against the best-of-breed available products. This helped in taking conscientious decisions coming up with suitable mitigation strategies that were based on situation at hand and the available resources with the organization. The mitigation strategies ultimately helped in bridging the gap between the reality and the objectives of the PLM System within the organization. An analysis was carried out considering the Pros and Cons of Single integral product development as against Best-of-Breed product selections. As it is decided to go in for the Best-of-Breed solution and interface or integrate the PLM solution with third party application tools such as DOORS, CATIA/IDEAS etc as appropriate and which were already existing/in the process of being procured, it was extremely important to pay extra attention to the integration process of the solution offered. In contrast to integrated solution, interfaced tools have some inherent disadvantages which needed to be addressed. Conditions were addressed in the specification document for the SI to mitigate the risk of an interfaced solution.

### **BALANCING ACTS, CHALLENGES AND IMPLEMENTATION CAVEATS**

**Out-Of-The-Box (OOTB) vs. Customer-specifically configured or customized PLM solution:** Many a times it is difficult to deploy the OOTB solution as is, especially as some of the areas have not reached the maturity level wherein the user can comfortably adapt to the working of the system. At such times the configured or customized PLM solution is preferred. However, there are down sides to customized solutions that need to be carefully assessed. OOTB PLM solutions are easy to maintain and migrating to newer version is much simpler. The OOTB features in newer versions may come out at a faster pace and also may far exceed the professionalism with which the customized versions are configured as the R and D professionals behind the scene at the OEM are focused completely on PLM development. If version migration requires substantial effort due to large customization, then the user may be stuck with the customized version which may be far inferior to the newer



OOTB versions released. However, as very many required essential features were unavailable OOTB and there was no view of the next version being available anywhere in the near future, a conscientious decision keeping in view the Version Migration aspects was taken to go in for customization to suit the needs.

**Version Migration:** The amount of customization carried out is directly proportional to the efforts associated in Version Migration. It is extremely important to strategically look at Version Migration Methodology right from the onset and have a roadmap of plan associated with the implementation and maintenance of the PLM solution. Decisions on trade-off of the need for the required features that are unavailable as against the efforts needed to migrate to newer version (which may have the features built-in as OOTB in part or full) needs to be carefully studied. The existing data which will at the time of migrating to the next version will be legacy data which may have to be kept.

**SI and Original Equipment Manufacturer (OEM) partnership:** The marriage between the SI and OEM is an important aspect that needs to be looked into. Trade-offs needs to be carefully balanced and weighted between the suitability of product to the environment and the strength of the marriage between the SI and the OEM. As the OEM had several sales distributors and also several implementation partners, it was extremely important to segregate them during the evaluation process. The Centre also made a tri-party agreement that was signed by both the SI and OEM so that the OEM provided complete and total technical support to the SI throughout the process. Infact it is to the credit of Centre, the OEM has submitted that many of the feedbacks given during the implementation have gone into incorporating features in the next version available in the market today.

**Strategic commitment at enterprise level:** PLM is a 'horizontal' i.e. a wide functional totality involving stakeholders across the enterprise, a systematic method that attempts to control the product data. Business backbone for maintaining Integrity, Reliability and Traceability of Information is a must. As absence of discipline in the process is often a large problem, it is important to strategically control and steer the process of creating, handling, distributing, and recording product related information right from the top level. PLM is essentially a management system that bridges the gap across various cross functional entities. Cultural and Organizational issues arising from the need to integrate a variety of core processes and to meet differing users are required to be addressed often and this can be strategically carried out only by means of top level commitment to PLM implementation. For this the vision and mission of the enterprise needs to be intertwined with the vision and mission of PLM.

**Knowledge of business processes essential:** PLM implementation is an extensive project involving detailed and laborious definition of various features of the business processes of the enterprise. Knowledge of one's own business processes and development, as well as of the features of the information processing system to be adopted, is of primary importance.

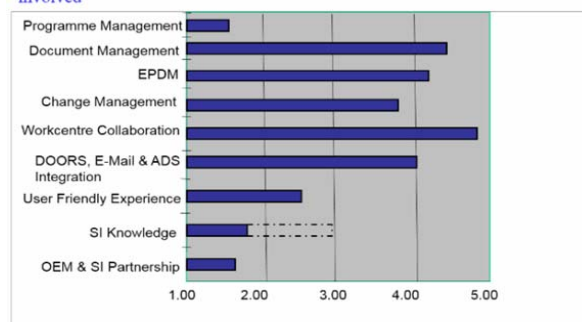
**Extensive resources utilization:** PLM implementation requires big investment in time and money. It will often bind the company for years to long range development and reliance on external help. Even after large investments, the risk of such an implementation is that it cannot guarantee that its adoption will succeed perfectly in any particular company. The System provides a communication forum for daily working, investment in user training at all levels is therefore essential. The system requires fast and secure networked operational business environment with powerful inter-company networking. Poorly structured collaborative infrastructure and inadequate infrastructure will doom any PLM implementation.

**Management of user privileges and information security:** Users at many times perform more than one role. It comes naturally for users to perform all tasks assigned to them under their own *single identity*. In the PLM system however, the access controls are *role based* and are defined as such. A person wearing different *hats* would have different privileges defined with each of the *hats* he is operating in. It is therefore important to create and manage the roles and associated privileges for ensuring the information security provided by PLM systems.

## SATISFACTION LEVEL

The graph in Figure-3 indicates the level of Satisfaction achieved at customer end in each of the Solution Area's along with the satisfaction in respect to the Graphical User Interfaces (GUI's); Integration aspects in respect to DOORS/Active Directory Service (ADS)/ E-mail Notification, Knowledge possessed by the SI and the marriage between the OEM and SI.

Satisfaction in Meeting Requirements with respect to Customization Efforts involved



Level of Satisfaction : 1 Bare.....5 Complete Satisfaction of actual application of technology in it's final form  
 ----- Indicates enhanced knowledge of SI during implementation

Figure-3. Level of satisfaction at customer end.



The satisfaction was measured with respect to the amount of customization that was required to be carried out in each of the solution areas.

## CONCLUSIONS

PLM solutions are the latest advances to drive productivity for effective management of Programmes, Projects, Organizations, People, Processes etc. However, in reality, it is seen that PLM solutions available today are nothing but an extension of PDM that are essentially Product focused with maturity attained essentially in the mechanical arena. Business Process Improvements (BPI's) over the decades have seen movement from Business Process Re-Engineering (BPR), Theory of Constraints (TOC), Total Quality Management (TQM), Enterprise Resource Planning (ERP) to now Product Lifecycle Management (PLM). Though PLM has come a long way and attained maturity in integrating the mechanical environment, it however has a long way to go before one can move forward from Organizational and Project Oriented Silos to Spider Web Organizations that have the ability to manage their Programmes/ Projects through a single source of truth as the basis for development of all their products.

The PLM implementation for the AEW and C Programme was an initiative taken up for enabling all the stakeholders in contributing in meeting the IAF requirements within the envisaged time and cost frames. The mission was to enable all the 'AEW and C Stakeholders' to effectively work at their efficient best. PLM requires a change in mindset. The environment for this kind of working needs to be continuously nurtured and at times even enforced. In order to have a major impact of such advancing and enabling technologies, a corporate-wide focus on effective management of information should be a rule, not the exception. Whatever be the case, few stakeholders achieving even any one of the minimum wins of such systems as newer and faster ways of working, enabling one to deal with increasing product complexity, helping one to innovate more quickly, gaining true control of product development process, provide for the ability for Integration and empowerment of design, engineering and other cross functional teams, supporting strategic sourcing, reducing non-value adding activities, better stakeholder connect etc. can go a long way in reducing timelines and in meeting the requirements to a large extent as has been the case in the development of the AEW and C Programme. Though PLM is not panacea or magic wand with which we can wish away the silo mentality that is responsible for all the ad-hoc, duplicate, hidden and inconsistent information that we work with each day but it is a start to creating an environment that is harmonious, integrative and wholesome. Most of all it can be synergistically managed.

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