

INNOVATIVE PROCESS MODELING & SIMULATION TECHNIQUES FOR AEROSPACE SYSTEM INTEGRATION SKILL DEVELOPMENT

R. SOUNDARA RAJAN

ME, MBA, PGDITM (GM), PMP (USA), [SMP (IIMC)]

Dy.General Manager, Bharat Dynamics Ltd

Hyderabad, Telangana

Email id: rsrajan2006@gmail.com

ABSTRACT:

In aerospace and defence industries, the complex system integration assembly and testing demands higher degree of accuracy and systematic manufacturing process to meet the aerospace quality requirements. It requires precise synchronization during developmental, Production and deployment phases. The paper highlights the innovative process engineering techniques viz. High level process Flow charts 3 dimensional Process Animation, Graphical user interfaced process module with voice encoded and process templates developed for aerospace systems integration assembly and testing. When configuration version changes corresponding process changes are to be incorporated in cross root level for better traceability. Developing innovative process improvement techniques using advanced technologies at operational level to train the technical work face in overall systems greatly helps to understand the critical and complex avionics manufacturing assembly and testing operations in simpler way. These techniques were proved in strategic missile projects for skill development, quality improvement, productivity improvement, resource optimisation, timely delivery and avionics certification of technical team. These techniques made significant impact in change of working environment, improvement of aerospace quality and productivity during subsystem assemblies, testing, reworks, refurbishment, post deployment services, life extension of complex missile systems.

Keywords: 3D Solid Models, Process Animation, Process Flow Charts, Graphical User Interface, Process Templates.

INTRODUCTION:

In the complex aerospace and strategic complex projects, manufacturing, assembly, integration and testing processes are more challenging area. A small process deviation leads to devastating mission failures because, it is very difficult to troubleshoot and simulate mission failures. This paper presents innovative process engineering techniques to overcome these problems and helps for resource optimization. These techniques also used as effective tools for Training and certification of aerospace technicians within very short span of time.

PRESENT SCENARIO:

- Due to the physical limitations of technical workforce like age, visibility, physical stamina, patience in the conventional methodologies, the workmanship, quality and productivity are diminishing day by day. The rate of failure in the process and manufacturing of aerospace systems are 52% as per the NASA research studies as shown in figure 1.

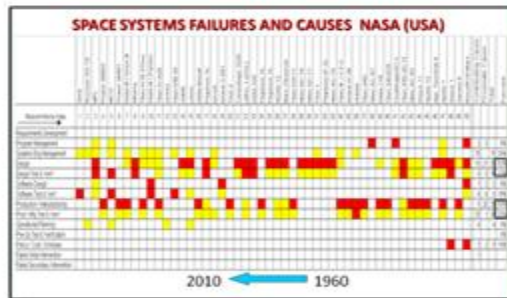


Fig 1: Process related system failures

- This causes frequent, repeated reworks; decreased workmanship standards to deliver the system with just met the quality aspects. This creates highly complex environment with lot of conflict, disappointment, demoralize the workman.

- Resulted very serious failures of critical systems during environmental, climatic testing, storage condition, transporting and storing long distance areas. Also it delays in delivery up to 40% of planned schedule.
- Hence the organization loses its images and business opportunities many times in the competitive environment. By which the programme is unable to meet the security needs of our country.

Solution to the Existing Scenario:

- The initiatives taken to develop a system to change in working environment without stress & strain by utilizing Technical availability helped to make change among the working group, complex integration & testing process leads to series of successful demonstration of flights and created positive synergy among the workers to willingly contribute their share by understanding the importance of the systems and criticality moreover the value of time and cost of our organization.
- The quality and productivity is improved and team gets complete system knowledge and sequence of process in their own area and relevant area by self-learning methods.
- The complex systems and technology made available to them in simple and elicit manner.
- This is helped management to easily develop multi-tasking work force with high precision. This methodology reduced the dependencies of highly knowledgeable engineers and scientists.
- The shop floor level technical team member can understand the systems, subsystems, assembly, integration and testing processes pictorially and by 3 dimensional movie types.

Need for Process Modelling:

Whenever the configuration, design changes the corresponding processes are to be amended and implemented to the cross root level simultaneously. System integration demands highest synchronization in development, implementation, testing and deployment and delivery service.

The approval process and communicating the changes to all the relevant people, establishing the mechanism to monitor, control and co-ordinate these changes are to be done parallel manner without hampering production quality and delivery schedules of the system.

Significance of Process Modelling Techniques:

Developing a system using advanced technologies to create pictorial representations to the operational level to train the technical work force in overall systems and understand the critical and complex operations in a simple way to understand and execute the operation is main concept.



Fig 2: Assembly process flow charts

This helps substantial savings of money, time, efforts and improved the workmanship standards, quality of the product and timely delivery with '0 %' rejection and train trade technicians of non-missile integration experience, various age group and varied background within short span.

Technique1: Design of Process Flow Charts:

The Process Flow Chart display total process flow of operations, inspection, testing and clearances of complex system assembly and refurbishment works in a very simple and pictorial representation form.



Fig 3: Std format process flow chart

The right hand side of the process flow charts will give complete information viz. Standards, relevant Specifications-Documents, tools, inputs etc. The left side of the charts will depicts, assembly, integration, testing process, specification standards of testing procedures and related critical instructions are to be followed by operators.

The main part of process flow chart will replaces critical operations of voluminous process documents / records in simple step by step sequential flow. It also covers the inspection stages, corrective measures, rework and repairs.

Need For Process Flow Charts:

- In a complex, multi engineering field of Avionics Industries especially in Missile Industries, the processes / operational documentation is cumbersome and herculean task to prepare, maintain, review and follow for any technical work force like ground level technician, inspector, operators.



Fig 4: Extended process Flow Chart

- Many times, there was number of human error caused failure of systems at various levels which not only delayed the projects but for considerable loss of time, efforts, money leads confusions. The quality of products lost its stature.

Features of Process Flow Charts:

- An effort being made to simplify the complex processes / operations into a simple yet pictorial representation in the form 'Process Flow Charts'.
- The right hand side of these charts will give the complete information about the standards to be used, documents required, tools to be used, type of inputs, specifications of inputs and so on.
- The left side of these charts will depicts, the assembly, integration, testing process, specification standards of testing procedures and related critical instructions are to be followed by operators.
- The main flow of the process flow chart will simply replaces critical operations of voluminous process documents / records in the simple step by step follow up of sequential operations.
- It also covers the inspection stages; corrective measures rework and repair mechanism as well.

Add-on features of process flow charts:

- Whenever there is a change in configuration change or version change, there may be a change in processes.
- In each cases, these charts will be used a better 'traceability records' and when failure occurs in any sub system or system level, it helps to decode the failure analysis in a systematic way to trouble shooters especially those experts from external to the projects / working department level.

Impacts of Process Flow Charts:

- The aesthetic feature of these flow charts are – these charts will be made available on the shop floor, in front of the operators, technicians, respective inspector to follow the sequence, to know the correct standards, tools, inputs, procedures all at one sight.
- If any new operator starts working this pattern, the human error is completely eliminated and systematic workmanship standards implemented.

Technique2: Design of 3DProcess Animation:

This process animation used in trial assembly, final assembly, preparation of various stages of and Integration, testing. The sequential operations of each components, sub systems and systems shown systematically.

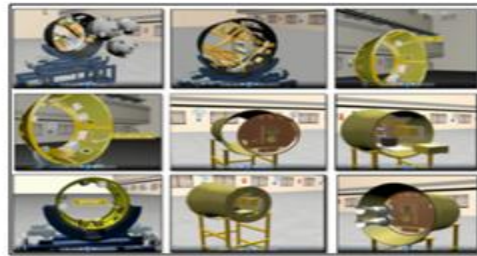


Fig 5: Concepts of process Animation

Voluminous 2D process drawings were converted into 3D dimensional using animation software with voice enabled to make mechanical, electrical assembly & testing processes. Approx 3400 processes are brought into 7min visual show. Whereas the conventional mode it takes about 4-6 Months to understand the complex processes.

The animation technology used to achieve concept of virtual assembly of complete missile, from the smallest nut and bolt to launch able ICBM missile without any materials!

Thousands of frames in various angles using available software. Developed frame by frame, integrated sequentially, developed stage by stage meticulously. It gives experience like digital movie.

Need for Process Animation:

- During dry assembly, trial assembly, preparation of various stages of production, assembly and Integration, the sequential operations of each components, sub systems and systems more systematic, correct process and operations.
- Otherwise there will be lot of confusion, rework, dismantling, re assembly again and again will cause lot of valuable man-hour wastage, resource conflict and de-morale of workmen.
- This condition leads bad quality, failure & fatigue. There is a need of a system which should support for basic workmen who cannot read and write English text and cannot understand high level technical terms.

Features of Process Animation:

- An effort being made to demonstrate the complex assembly processes in a pictorial form, sequentially.



Fig 6: Integration process Animation



- The animation technology helped to achieve my dream of virtual assembly of complete missile, from the smallest nut and bolt to launchable ICBM missile without any materials!
- The imagination kicked off my mind. Quickly I gathered all the drawings of 2D (two dimensional) and developed the concept of making thousands of frames in various angles using available software.
- Developed frame by frame, integrated sequentially, developed stage by stage meticulously. It gave me making a digital movie experience!

Impacts of Process Animation:

- Finally ended up a beautiful full movie of 'Process Animation- Making of Strategic Systems'.
- The concept is new. I applied all the process steps carefully in each stage. Actual Images of All the subsystems are modeled and embedded in the system.
- Correct name & Images of these subsystems provides real time understanding.
- I wanted to improve further by adding voice into the process animation to give more accurate results and understanding the lower level operators, technician who do not have such experience elsewhere.
- Making them more confident at first time itself and getting the work done correctly at the first time and every time was my motto.

Technology Involved in Process Improvement Techniques

- **3 Dimensional Platform:** Maya, Photo Director, Visual Studio, Photo Shop, Photo Editor & Solid work software packages used for Process Animation.
- **2 Dimensional Platform:** Idea software, Pro-E software and CAD Software are used for developing drawings and frameworks for out-lines of the system layouts.
- **GUI Software:** Dot NET framework 4.0, Windows Media Player for GUI based voice interactive module for process modules.
- **Application Software:** MS office – power point, word and excel are used to document and store the images, graphs, texts, flow charts, drawings etc.

Customer Acceptance:

When new group of technical team deployed, the tremendous interests shown by them for learning existing cumbersome processes and procedures in high level English and technical terms in the form of visual media, voice coded within 13 minutes of time, this tool worked well to make them perfect to make 100 % quality. The learning does not require any specialists or technocrat but for self-interest, volunteering and enthusiastic manner.

The project not only for wonder, but for bonding the systems, sequential processes deep into their mind. When the mind is habituated to do the right practices then, rest the system will take care automatically

Technique3: Graphical User Interface (GUI)

- Developed to understand pictorial view of Subsystems, Systems, Bill of Materials List, Process Flow Charts, Materials Specifications, Process Steps, Process & Testing Templates, Practical Videos of various
- Configurations and testing methodologies & procedures with multilingual voice coded. By moving cursor over the object, an operator can able to interact with computer using multi lingual processes knowledge.
- Flow Charts, Materials Specifications, Process Steps, Process & Testing Templates, Practical Videos of various Configurations and Testing Methodologies & Procedures with Multilingual Voice Coded.

Concept of GUI Based Process Module:

- Developed process module with the concept of technical workmen should be able to interact with computer monitor to get to train, understand various systems, sub-systems and testing of the systems.
- It gives the complete knowledge about the product he worked for. He can able to interact with computer using his / her language.
- He need not depend on English. He can converse with Hindi or local language as well. It is like any simple IVRS system of Indian Railway Reservation System.

Salient Features of GUI Based Process Module:

- It will give overall systems and product specifications, configuration & versions
- Guide the technician to learn system wise and sub system wise details pictorially.



Fig 7: GUI concept Model layout

- He / She can see the actual Image of the system, Bill Of Material lists and so on
- It shows pictorially all the input materials, tools, process flow charts etc.
- Process video and process animation loaded in the module to access & view
- Operational Process Flow diagram and micro level flow charts are available Final Integration,
- Testing of variants included in the module Common processes, Test formats, Signal flow Line diagrams are made available
- Voice enabled for placing the cursor over the icon gives added advantage to user

Impacts of Process GUI Based Process Module:

- The process module is self-explanatory and simple to use for anybody who have basic knowledge about computer.
- This work as quick training tool for a trainer for training and certification of workmen-ship to embrace complex system integration and testing field.
- The complete system knowledge will help them to work in various working environment and gives less friction for change management from one area to other.
- The cost effective tool gives quality & productivity for organizations.
- During the Assembly, Integration, Testing, Rework, Modification period, this will help the technical team to carry out their work very systematically without human error

Benefits of Process GUI Based Process Module:

- The operator need not have highly technical knowledge and conversant with English terminologies.
- The complete module is designed in such a way that the operator learn himself i.e. self-explanatory.
- The language barriers can be eliminated completely.

- Any operator can become system knowledge person and can easily understand the processes while doing right things every time.
- The quality and productivity is improved a lot for any complex industries.



Fig 8: Cable harness template with cut view of one section

Technique 4: Process Templates (Cable Harness & Hydraulics Systems)

a) Electrical Cable Harness:

- The Aerospace and Defence Cable Harnessing requires very systematic sequential process implementation. At the same time, the rate of production also needs to be taken care.
- Templates for cable harness will help to meet above requirements without compromising quality of the products
- Cable harness templates are most useful when configuration and version is vetted.
- The lengths of aerospace systems cables should be fixed with close tolerance.
- Figure 7 shows a cut view of sectional cable harnessing template, simulated with miniaturised packages and hardware interfacing.
- Each loom in the harness are numbered as per the data sheet of the concern section or systems in the equipped section.

b) Mechanical (Hydraulics) Templates:

- Mechanical Templates especially in specialised area like Hydraulics, Pneumatics and Plumbing plays vital role in aerospace system integration and system assemblies.



Fig 8: Hydraulic plumbing template

- These templates will gives three dimensional view, which cannot be made in two dimensional drawings.
- Most complicated systems can be simulated in better manner using these templates.



- The rate of production with highest quality and zero rejection can be achieved using these templates.
- Figure 8 shows one example of hydraulics plumbing templates used in highly complex control systems in aerospace applications.

Expected outcome of Process Modelling Techniques:

These process improvement techniques has helped the assembly & testing, more systematic understanding of total systems, foolproof process for assembly, tech modifications, up-gradation, testing with zero defect quality testing, zero rejection, improved productivity, advanced delivery schedules and achieved significant profit and image for the organization

Cost Benefit Analysis:

a) Conventional Methods:

To assemble and testing one article, assume 'X' hours will take. For Reworks, Repairs, Replacements & Retests of 1 article 'X' + 10% hours will take.

For Example, X=10,000 hours, then 10% of 'X' is 1,000 hours taken additionally to complete one article. If we convert costing, 1 hour = Rs. 2900/- (FY 2015-16) For 1000 hours = 1000 x 2900 = Rs.29,00,000 = USD 43,284

If we consider the rate of manufacturing is 4 articles per year, then the total cost incurred is = 4 x 43,284 = USD 1,73,136 = 0.173136 million USD i.e. **0.173136 million USD Revenue Loss** for one project per year. This also **reduced the Productivity & Quality by 10%. Most import fact is 'Mission Failures'**.

b) Implementation of Process Improvement Technique

After implementation of the process improvement techniques 1,2,3, then Expected production rate will be 12 **articles** per annum Productivity will be Increased by 3 times with Improved Quality by 10% **For Example, 0.519 million USD can be saved straight away** (3 times of 0.173136 million USD) More important fact that, **'Mission Failures' could be avoided due to Process Failures**. In addition to that, the operational profit for the project is 3X hours @ Rs.2900/-. In this case if X=10,000 hours, then 3x10,000x2,900=Rs. 870,00,000 = 1.298million USD. Estimated Operational Profit is 1.298million USD per year.

Organizational Impact:

The pilot project gave innovative solutions in the area of Reduction of Inspection and Testing Time, Quality Improvement, Process Improvement, Technology Improvement and House Keeping. These innovative solutions were made direct impact on the complex missile production and delivery.

Nurturing & furthering Technological Development:

- Development of Multi Lingual GUI based Process Interactive Module with voice enabled to help much more understanding the technology, complex process and technical terminologies in his/her own mother tongue.
- Micro level components / elements break up from system / sub system assemblies which enable to understand visually by any operators / technicians. Which will completely eliminate the human error in using wrong components due to lack of knowledge? Complete traceability can be achieved by this method.
- Dis-Integration and Dis-mantling Process Animation – will give visual processes and eliminate human error during implementation of modification, changes at field.
- Unified Codification of Components / Elements – will give traceability of each component, supports procurements, stores & spares management systems.
- This will help to prepare precisely the Bill Of Materials (BOM) of each configuration and version. When changes are made, it gets automatically updates and keeps records of changes.

- Remotely Operated Processes/Drawings/Data Sheets/Operations – LCD based touch panel will be used to access the required drawings, operations, processes and operational sketches will improve the operational capabilities and paperless environment. The operator can access any data within seconds. This will reduce lot of times and efforts at shop floor level.

Organizational benefits out of this project:

- The working environment changed from normal, conventional to ultra-modern production facilities in avionics industrial environment.

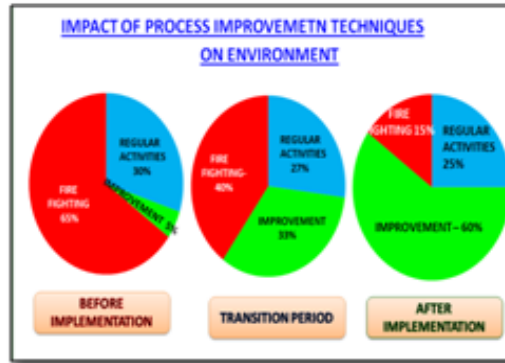


Chart1: Organizational impact of process techniques

- It creates better image of the organization when visiting VIPs and Top level Executives from government ministerial level.
- The quality product is ensured and the organization demands its supremacy / leadership in the concerned field.
- The employees willing to work more with comfort environment by which the quality and productivity is improved a lot consistently.
- It is easy to get international standards certificates like ISO, SIX SIGMA and so on.
- The organization gets lot of new business orders and opportunities in future.
- The stakeholders and users of the product gets confidence on the organization.
- The same system can be extended to other divisions / projects to improve overall productivity and revenue of the organization.
- It helps organization to have uniform standards and best production practices of its products / processes.

Validation & Certification Agency:

The above model will be inspected in each stage and to be validate by the following Quality Assurance Agencies:

1. Quality Circle Forum of India (QCFI)
2. Reliability & Quality Assurance Agency (R&QAA)
3. Strategic Systems Quality Assurance Group (SSQAG)

Standardization of innovative model:

- The pilot model proved in the pilot project stage at organizational level and success rate was attained to 100% with '0 %' defect products delivery and services.
- The other industries / Labs were Implemented this process model are,
 1. Ordinance Factory Board (ORDF)
 2. Advanced Systems Labs – DRDO
 3. Mazegon Deck Limited (MDL)

CONCLUSION:



The impact of innovative process engineering techniques has helped to improve productivity, process clarity; technology implementation, resulted in reduction of overall manufacturing cycle time, elimination of human errors in process related, reduction of material wastages, and reduced rejections in over all work centers.

ACKNOWLEDGEMENT:

- [1] Dr. MRM Babu, Sc.-'H', Outstanding Scientist, Programme Director, ASL-DRDO
- [2] Dr. VVRAO, Sc.-'H', Director, CAS [ASL-DRDO]
- [3] Sri. P. K. Diwakaran, GM (Rtd), BDL

REFERENCES:

- [1] *Failure Space: A Systems engineering look at 50 Space System Failure-J.S. Newman NASA-Act an Astronautics Vol.48 No 5-12*
- [2] *Process Improvement Techniques by Quality Circle Forum of India, Secundarabad.*
- [3] *Reliability & Quality Assurance Agency (R&QAA)*
- [4] *Strategic Systems Quality Assurance Group (SSQAG)*
- [5] *Strategic System Centre (SSC) – ASL*
- [6] *Centre for Advanced Systems (CAS)*

About Author:

R. Soundara Rajan is Deputy General Manager and Head in Process Engineering Department, Bharat Dynamics Limited, Centre for Advanced Systems (Advanced Systems Laboratory). He has received National Quality Circle Excellent Award; National Quality Circle Distinguished Awards in Quality Circles for Process Engineering Innovation Models used for skill development of avionics technicians. He is a recipient of Gold Medal in PGDITM and Special Merit Awards for various Innovations in Process Engineering, Quality Circles and Advanced Project Management fields. He bestowed with 'Researcher of the Year Award-2014' by the PIMG (Gwalior) and Project Management Practitioner in 2013. He is an active member of more than 25 National and International Technical and Management Professional Bodies.