Research on Aerospace Quality Improvement Solutions

*Bo Duan**
Quality Management Institute
China Academy of Aerospace Standardization and Product Assurance
Beijing, China
duanbo816@163.com

*Yang Gao**
Quality Management Institute
China Academy of Aerospace Standardization and Product Assurance
Beijing, China
86454635@qq.com

*Lu Li**
Quality Management Institute
China Academy of Aerospace Standardization and Product Assurance
Beijing, China
1242556336@qq.com

Hongtao Yao
Quality Management Institute
China Academy of Aerospace Standardization and Product Assurance
Beijing, China
236185235@qq.com

***Abstract*—This paper discusses the concepts and methods of six sigma and the main quality improvement models at home and abroad, combines the demand for aerospace quality improvement with existing effective methods and experience with aerospace quality improvement, proposes the connotation and general idea of aerospace six sigma improvement, forms a systematic and structured improvement model of discernment, analysis, improvement, assessment, and sharing methods in aerospace oriented to problems and weak links. Through integrating quality improvement methods, this paper establishes solution processes for different types of aerospace quality improvement projects.**

Keywords—Aerospace; Quality improvement; Six sigma improvement

I. INTRODUCTION

The new development trends and task characteristics of aerospace engender higher requirements for quality management capabilities and levels. The development of the aerospace science and technology industry today is more than ever dependent on quality management, especially the technical support of advanced quality methods. Quality management and control need to become even more standardized, systematic, scientific, and quantitative, and need to draw on lessons from the advanced concepts and methods of foreign quality management. Integrated within its context, aerospace quality improvement methods can be established and enriched. Aerospace quality management and quantized control capabilities can be promoted to ensure the success of industry development, production, and experiment with aerospace model types.

The six sigma method originated in America at the end of 1980s. After decades of development and wide application around the globe, today, six sigma has developed far beyond its statistical application, having become a management style and system for design optimization and continuous improvement, driven by customer requirements [1–2]. The six sigma method includes six sigma design and six sigma improvement, which is the most widely used. Facilitating the continuous improvement of quality is a permanent pursuit in the aerospace industry. To this end, it is necessary to combine advanced six sigma improvement ideas and methods with the characteristics and requirements of aerospace quality improvement, forming an applicable, unique, aerospace six sigma continuous improvement approach [3]. By doing so, Aerospace quality management and quantized control capability can be promoted.

II. OVERVIEW OF AEROSPACE SIX SIGMA IMPROVEMENT

A. The Concept and Characteristics of Six Sigma Improvement

The essence of six sigma improvement is its quality improvement methodology [4]. This introduces project management methods, and realizes the effective identification, analysis, improvement, and control of quality problems and weak links through a set of scientific, standardized processes, and related quality techniques and methods integration [5]. Compared with traditional quality improvement processes, the outstanding aspects of six sigma improvement are:

Customers' requirements and identification of key quality characteristics are emphasized; the use of data and the quantification of the quality improvement process are emphasized; the integrated application of quality techniques and methods are emphasized; and the financial data evaluation of quality improvement results are emphasized [6–8].

B. The Main Processes of Six Sigma Improvement

As for the six sigma improvement processes, the Define, Measure, Analyze, Improve and Control (DMAIC) process is most widely used [9–10]. Most organizations, such as Motorola and GE, working for the United States Defense Department, adopt the traditional DMAIC improvement process [11]. At the same time, some enterprises develop DMAIC processes based on the idea of six sigma and combine it with actual demand. For example, Raytheon deploys an innovative VCPCIA (Visualize, Commit, Prioritize, Characterize, Improve, Achieve) of the six sigma improvement process [12], NASA proposes the Vision, Definition, Measurement, Analysis, Improvement, Control improvement process, and Lockheed Martin deploys the eight steps to excellence (Identify opportunities, Determine priorities, Define projects, Evaluate/Describe situation, Analyze waste/risk, Optimize processes, Reduce risk, Implement/Verify, Measure/Keep, Communicate/ Confirm success) [13].

C. The Concept of Aerospace Six Sigma Improvement

The goal of aerospace six sigma improvement is "zero defects," and to achieve this, the concept and methods of six sigma improvement is integrated with the aspects and experience of existing effective quality improvement in aerospace. Aerospace six sigma improvement is the continuous and systematic identification, analysis, improvement, and control method and solution process oriented to quality problems and weaknesses in aerospace.

III. THE GENERAL IDEA AND MODEL STRUCTURE OF AEROSPACE SIX SIGMA IMPROVEMENT

A. General Approach

With the core of the system to promote quality, six sigma and main quality improvement models at home and abroad are referenced, and the concept and methods of six sigma are combined with the characteristics and demands of aerospace quality improvement. Existing effective methods and tools are integrated, and a systematic and structured improvement model is formed including discernment, analysis, improvement, assessment, and sharing methods oriented to problems and weak links in aerospace.

B. The Basic Model of Aerospace Six Sigma Improvement

The basic model of aerospace six sigma improvement is shown in figure 1.

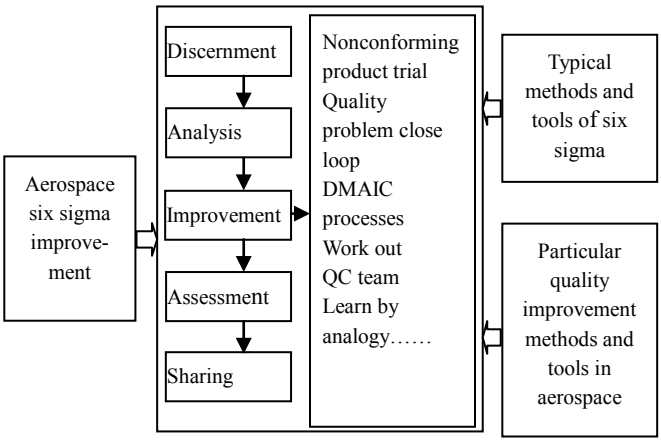

Fig. 1. The model structure of aerospace six sigma improvement

Compared with traditional six sigma improvement, the variation for aerospace six sigma improvement is largely reflected in the following:

1) The traditional six sigma improvement process is extended, and the management process and the discernment of problems and weak links oriented to the organization (department) is formed.

2) The recognition and analysis of improvement projects are regarded as two stages ("discernment" and "analysis") in aerospace six sigma improvement, which are not fully covered in the traditional DMAIC processes. However, the two stages are very important in the beginning of the DMAIC process, as they determine the pertinence and effectiveness of subsequent quality improvements.

3) The related quality improvement process methods (such as the nonconforming product trial, quality problem close loop, DMAIC processes, work out, QC team, and learn by analogy) are integrated and brought into the "improvement" stage of aerospace six sigma improvement. Different types of projects discerned and confirmed adopt different improvement processes.

4) The evaluation and sharing of improvement projects are regarded as two stages of aerospace six sigma improvement. The two stages emphasize the assessment of project improvement results and the summary, refinement, and sharing of project improvement achievements, which are not regarded as independent stages in traditional DMAIC.

IV. THE MAIN PROCESSES OF AEROSPACE SIX SIGMA IMPROVEMENT

A. Discernment Stage

In the discernment stage, a comprehensive analysis of quality is carried out through a variety of ways and means to discern improvement opportunities and directions. The main task, activities, technical methods, and outputs of the discernment stage are shown in TABLE Ⅰ.

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TABLE I. DISCERNMENT STAGE

Main Task	Main Activities (Steps)	Main Technical Methods	Outputs
Discern improvement opportunities	—Determine the ways and means of discernment opportunities —Carry out quality analysis oriented to products and processes —Collect relevant data for quality analysis and assessment —Comprehensively analyze quality data —Discern the improvement opportunities	—Value stream analysis —Quality analysis oriented to products —Quality management system assessment —SWOT analysis —BSC —Quality intersection analysis —Pareto diagram —SIPOC —VOC analysis, etc.	—Problems and weak links list

B. *Analysis Stage*

The analysis stage is to analyze the common problems and weak links that offer improvement opportunities, and determine specific improvement projects that can be implemented. The main task, activities, technical methods and outputs of the analysis stage are shown in TABLE Ⅱ.

TABLE II. ANALYSIS STAGE

Main Task	Main Activities (Steps)	Main Technical Methods	Outputs
Determine improvement projects	—Analyze the common problems and weak links that offer improvement opportunities —Determine the range of improvement projects and clear priorities —Decompose the improvement projects, and form a series of clear and specific improvement projects —Analyze the feasibility of the improvement projects —Register the improvement projects decided on.	—Discernment of common problems —WBS analysis —Project approval table —Brainstorm —Cost analysis, etc.	—Improvement projects list —Project approval table

C. *Improvement Stage*

The problems in improvement projects generally include three types; the first are obvious problems, which are quality problems exposed and impacting aerospace project development and production processes, including the quality of outsourced products. The second are hidden problems, which are underlying quality problems not directly exposed or making an impact on aerospace project development and production processes. The third are common project problems. Common problems represent a series of problems with some common factors for a period of time and in a certain range. The common factors can be the causes or the manifestation patterns such as products, units, or models in which problems frequently occur.

For quality problems that have been exposed and discovered, one solution process is the nonconforming product trial aimed at quality problems. The nonconforming product trial system consists of different classes of nonconforming product trial systems such as a supplier nonconforming product trial committee as well as a permanent organization (quality management department), a nonconforming product trial team, and trial personnel. There is no need to implement the quality problem close loop method if the problems can be solved through the tolerance list, change list, and question list. The disposition of the nonconforming product trial could be rework, concession, degrade, convert to other use, rejection, or scrap.

Another solution process is to use the quality problem close loop. This is mainly used for quality problems that are not suitable or unable to be solved by the nonconforming product trial. The criteria for the quality problem technology close loop process are: exact location, clear mechanism, problem repetition, effective action, and learn by analogy. The criteria for the quality problem management close loop process are: a clear process, distinct responsibility, action fulfillment, seriousness, and consummate rules.

For the hidden and common problems, the DMAIC model, QC model, learn by analogy model, and the Work out model can be applied according to the type of project. TABLE Ⅲ describes the main improvement methods in the improvement stage.

TABLE III. THE MAIN IMPROVEMENT METHOD IN THE IMPROVEMENT PHASE

	Model	Application Range	Procedures
1	Quality problem close loop	Quality problems have been exposed and are making an impact on aerospace project development and production processes, and cannot be solved by nonconforming product trials.	*1)* Exact location，clear mechanism， problem repetition， effective action，learn by analogy, finish close loop report. *2)* Find out quality problem occurrence process, distinct responsibility, action fulfillment, address seriously, consummate rules, finish management close loop report.
2	DMAIC	Mainly target the improvement projects for weaknesses and hidden trouble in management or technical processes identified by quality analysis, which are complicated administrative problems.	Define, measure, analyze, improve, control.
3	QC	Mainly target the relatively uncomplicated improvement projects, which are identified by working teams quality analysis. The projects can be solved within the scope of the working team.	Select problem, investigate, set target, analyze, confirm primary cause, develop plans, take action, evaluate effects, formulate measures of consolidation, summary, and next steps.
4	Learn by analogy	Mainly target projects related to the products where quality problems already occur, or with similar mechanisms.	Based on the quality problem information (quality problem close loop information), collect quality problems from other products which

			occur and already solved, find out whether similar mechanism problems occur in our products, our organization, including other products and relative organizations, take actions to solve the hidden trouble, and prevent its recurrence.
5	Work out	Mainly target the management improvement projects identified by quality analysis. To solve the issues, needs multiple sector coordination.	Define business issues and identify key events; Set up a design team and discuss openly; Set range, vote on important issues; Establish issues logically and systematically; Line up issues according to priorities; Turn issues into targets; Determine the core team members, and assign roles and tasks; allow freedom to discuss the solution to the issues; Display ideas; Define issues again and test the target hypothesis; Evaluate and filter the solutions; Convene meetings and make decisions; Develop an action plan and identify implementation steps; Confirm person in charge; Turn ideas into actions; Inspect actions.

D. Assessment Stage

The assessment stage is used to evaluate the results of the improvement projects compared against the anticipated targets. Through the assessment, the results of the improvement projects can be judged and mastered quantitatively. To a certain extent, the stage also acts as a means of supervision and incentive. The main task, activities, technical methods, and outputs of the assessment stage are shown in TABLE Ⅳ.

TABLE IV. ASSESSMENT STAGE

Main Task	Main Activities	Main Technical Methods	Outputs
Evaluate the results of improvement projects	—Determine the assessment scheme, clear assessment procedures, and methods —Collect the required data for assessment —Implement the assessment and review of different projects —Analyze the assessment results comprehensively	—Delphi method —Customer satisfaction evaluation —Statistic analysis —Review	—Project improvement assessment results

E. Sharing Stage

The sharing stage is deployed to summarize the achievements of the improvement projects, refine relevant information on project improvements, and establish a database of project improvement achievements. It can provide experience for relevant personnel and empirical support for quality improvement, and thus promote knowledge sharing. The main task, activities, technical methods and outputs of the sharing stage are shown in TABLE Ⅴ.

TABLE V. SHARING STAGE

Main Task	Main Activities	Main Technical Methods	Outputs
Summarize, refine, and share the achievements of improvement projects	—Summarize and refine the achievements of improvement projects —Collect data on projects and implementation —Put data into project information management system —Share the project information	—Visual management —Database	—Project achievement information table

V. CASE STUDY

The pilot application of the aerospace six sigma improvement process was carried out in one aerospace department. In the discernment stage, the histogram, the Pareto diagram, the SWOT analysis, and other methods are used. By analyzing related information output about the nonconforming product trial, quality management system evaluation, and quality supervision work over the last five years, the common problems and improvement opportunities were identified; In the analysis stage, the improvement project list was determined, including reducing the error rate of the welding line, optimizing the material support process, reducing the generation rate of manual welding tin sweat, and learning by analogy about the foreign problems in the production process, among others. In the improvement stage, different improvement methods were determined according to different types of projects (DMAIC, quality problem technology close loop, quality problem management close loop, work out, learn by analogy, and QC group). In the assessment stage, the effect of each improvement project was evaluated by a judged conference and a report conference. In the sharing stage, the related information on improvement project achievements was summarized and shared. Through the pilot application, some weak links and common problems that had been identified were solved, and the improvement achievements were solidified. At the same time, the operability and effectiveness of the aerospace quality improvement processes and methods were verified.

VI. THE CHARACTERISTICS OF AEROSPACE SIX SIGMA IMPROVEMENT

A. Reference Successful Experience of Six Sigma Improvement

The core characteristics and success factors of six sigma improvement are referenced in the model design for aerospace six sigma improvement including implementing quality improvement for projects, establishing structured quality improvement processes, comprehensively applying quality technical methods, emphasizing data, and evaluating the financial benefits of quality improvement results.

B. *Aerospace quality improvement methods are arranged and integrated*

Existing quality problem discernment, analysis, improvement, and control methods in aerospace are sufficiently considered in the aerospace six sigma improvement process such as the problem close loop, nonconforming product trial, quality analysis oriented to products, discernment of common problems, and QC team. These methods are arranged and integrated according to a certain logic and have become a very important part of the aerospace six sigma improvement.

C. *Apply Methods and Tools of Six Sigma To Aerospace Quality Improvement Processes*

Aimed at the requirements of the aerospace six sigma improvement process at each stage, the mature and efficient technical methods and tools in six sigma are embedded organically in aerospace six sigma improvement processes. Through the application of scientific, quality technical methods and tools, aerospace quality improvement is promoted and the rationalization and quantification of aerospace quality improvement is realized.

D. *Establish a Systematic Model and Methods of Problem Identification, Solving, and Information Sharing*

The concept and methods of six sigma are combined with the characteristics and demand of aerospace quality improvement. The systematic and structured processes and methods of discernment, analysis, improvement, and sharing, which are oriented to problems and weak links, are formed through integrating relevant methods and tools.

VII. Summary and Conclusions

1) Aerospace six sigma improvement is a configurable process used for quality improvement, aiming to put forward a resolved scheme for problems and weaknesses using similar six sigma methodology (e.g., QC, 8D, PDCA), essentially just different in some aspects in terms of range, process, and technique.

2) The characteristics of aerospace products and the development process including being highly technical, high risk, and highly complex, determine that the quality process must face new demands and new challenges in the processes of development and production. Quality support efforts are a very important program for identifying and solving quality problems. In recent years, the aerospace industry has discovered and applied several methods (e.g., quality problem close loop, product quality analysis, QC, evaluation of quality management system, identification and improvement of common quality problems, the nonconforming product trial, and learn by analogy). The basic ideas and the targets among these methods are different, but they are equally satisfactory in creating results according to the six sigma improvement process.

3) In this paper, the aerospace six sigma improvement model is an exploration of organically integrating the concept and methods of six sigma improvement with the characteristics and demands of aerospace quality improvement, a localized development of six sigma, and also the further extension, integration, and development of aerospace continuous improvement methods. It introduces the idea and methods of project management and project evaluation and provides a systematic and quantized tool used to improve quality. Moreover, it can act as a reference for more systemic and effective identification and improvement of quality problems, optimization of processes, and the promotion of quality assurance capabilities and quantized control levels.

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