

THE APPLICATION OF TOTAL QUALITY MANAGEMENT PRINCIPLES TO
SPACECRAFT MISSION OPERATIONS

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ABSTRACT

By now, the philosophies of Total Quality Management have had an impact on every aspect of American industrial life. The trailblazing work of Messrs Deming, Juran, and Crosby, first implemented in Japan, has "remigrated" across the Pacific and now plays a growing role in America's Management culture. While initially considered suited only for a manufacturing environment, TQM has moved rapidly into the "service" areas of offices, sales forces, and even fast-food restaurants.

The next logical step has also been taken - TQM has found its way into virtually all departments of the Federal Government, including NASA. Because of this widespread success, it seems fair to ask whether this new discipline is directly applicable to the profession of Spacecraft Operations. The results of quality emphasis on our contract at JPL provide strong support for Total Quality Management as a useful tool in doing Spacecraft Operations.

Key Words: Total Quality; Mission Operations; Continuous Improvement; Spacecraft Operations; Process Improvement

1. INTRODUCTION

The purpose of this paper is to explore whether the unique aspects of Spacecraft Operations make it a logical candidate for the application of Total Quality Principles. We all are aware of the growing percentage of Mission Life costs which now must be allocated to the Operations Segment. Can TQM provide an answer to this and other operations-unique problems ?

We can point to some direct experience to support the case for Operations TQM. In 1988, OAO Corporation was awarded the MACS contract, to support the Institutional Computing and Mission Operations Division's operational needs. As Mission

Operations Manager on this contract, I have been involved for nearly five years in providing Operations Manpower to the various Spacecraft Support activities of the Division. From the outset, this contract encouraged us to look for better ways of doing business, by making a significant part of our profit subject to continuous improvement. The intervening years have provided us with a very positive experience, and forms the basis for our belief that TQM in Operations is here to stay.

2. A PROGRAM BY ANY OTHER NAME..

Our own experience in Continuous Improvement, under the name Productivity Improvement and Quality Enhancement (PIQE), preceded the widespread popularity of TQM by a couple of years. However, the goals were much the same, namely, to look into the Processes which make up our operations, and find ways to improve them. The added benefit of TQM, once it came into our field of view, was to give structure to our search for efficiency. In retrospect, then, we were doing basic TQM in 1988, but have benefitted since by the broader vision offered by the formal TQM program.

3. DOES TQM PASS THE TEST FOR GENERAL SPACECRAFT OPERATIONS?

It is fair for Managers at other locations and with different problems to ask whether this experience can be "transplanted", or whether our positive experience is due to unique circumstances. In order to answer this question, I have decided to choose a popular summary of the TQM philosophy, and to address each of its points as to applicability to a Spaceops environment. Where applicable, our experience at JPL will be included to make the case.

Selecting a single source for defining "TQM" is at this point difficult. By now, thousands of articles and books have been written on the subject, many training courses have been taught, and Consultants ready to further educate us abound. Yet, for our purposes, I believe we can do no better than to use as a reference one of the early "Prophets" of Total Quality, namely W.E. Deming.(Ref 1) Dr. Deming is by now some

ninety years young, and was a prominent figure in the revitalization of Japan during the early 1950's. Although his complete message on quality transformation has filled volumes, he has distilled its essence into what he calls his Fourteen Points. It is against these standards that we will consider TQM viability to Spacecraft Operations.

4. DEMING'S FOURTEEN POINTS

4.1. Point 1. Create Constancy of Purpose. (The first job of an organization is "staying in business" by innovating and constant improvement.) That Spacecraft Operations would actually go out of business may seem to be a remote likelihood. Most of it is funded directly or indirectly by Governments, which have supported space exploration for decades. Yet, we know that, over even longer term history, scarce resources will be allocated according to perceived need and payoff. Thus, we must be sensitive to the cost-benefit decisions which occur each year at budget time, to make sure that the taxpayer will continue to see a positive value to our efforts in the exploration and exploitation of space. We must grasp new technologies, abandon inefficient methods, and always be looking for better ways of doing business. As Operations costs increase, Managers must use new paradigms for looking at workload. Can the next job be integrated into the current workforce? Are we using the most efficient technology? How can the process be improved?

On the MACS Contract, Managers have learned to look at each new requirement as an opportunity for economies. When possible, the process is reviewed and changed to accommodate the work. Adding costs without real necessity is not acceptable. This has resulted in such efficiencies as organization-flattening, job combinations, use of existing systems to eliminate new equipment costs, shift scheduling changes, and overtime elimination. Naturally, this philosophy does not maximize "Sales". However, due to the nature of the Fee structure, it can maximize profits.

4.2. Point 2. Adopt the New Philosophy. ("We need a new religion in which poor workmanship and sullen service are unacceptable".) For Operations, this means finding the causes of these problems and rooting them out. (As will be seen later, Deming believes most of them are with the System, not the people.) It is incumbent on Operations Management to create a fertile place for

innovation and quality, and which is equally hostile to poor attitudes. This requires attention to the special environment in which our people work, to their hours, their training, their level of support, etc.

Both JPL and OAO supervisors in the Division have received special training in the tools, techniques and principles of TQM, from a Consultant secured for that purpose. This top level training has since been augmented by selecting obviously-committed members of the Operations Teams for training, with the same Consultant. As a step toward integrating the program into our "culture", OAO has hired a full-time TQM Facilitator/Trainer to train the remainder of the workforce, conduct facilitated process improvement projects and maintain high program visibility.

4.3. Point 3. Cease Dependence on Mass Inspection. (Quality comes from improvement, not inspection). At first blush, this does not appear to have much to do with Operations. However, if we think about how we perform operations, it comes more into focus. Typically, organizations try for high quality by rework, not prevention. An example might be resorting to replay requests to fill "gaps" in data received from a remote station. This is trying to "inspect-out" errors, rather than build in quality. A more effective method is to determine and correct the cause of the gap. Once we begin to look closely at methods, we will find that there are many opportunities to implement improvement, and eliminate unnecessary QC steps.

4.4. Point 4. End the Practice of Awarding Business on Price Tag Alone. (Instead, seek the best quality in a long-term relationship with a single supplier.) The first step in this process has been taken. Operations "vendors" are generally chosen by competitive process which gives high priority to understanding of the requirements and demonstrated experience, not just cost alone. Also, the resulting contracts are for a fairly long term, some five to ten years. As a next step, I suggest that Operations contracts in general could benefit from the broader use of Award Fee structures to encourage Continuous Improvement, as in the case of the MACS Contract. As indicated earlier, a significant portion of total profit available is determined by proven Productivity Improvement and Quality Enhancement initiatives.

4.5. Point 5. Improve constantly and forever the system of Service. (Improvement is not a one-time effort.). Deming and all other serious TQM

practitioners are committed to the Continuous aspect of Continuous Improvement. Another proponent, Thomas Berry states this principle as: "Quality is A Journey, not a Destination" (Ref 2.) In Spacecraft Operations, this means a commitment to long-term, gradual, sometimes agonizing, change. Successes, sometimes small, will build on one another as the system continuously improves.

Continuous Improvement cannot be maintained, or even proven, without Measurements. One of the toughest hurdles in accomplishing TQM in Operations has been the proper selection of Metrics. Finding the right Metrics involves bringing the people doing the work into the process. Then, the products and customers must be identified, and some recurring activity, such as data item delivery, or command sent, or blocks thruput, chosen for monitoring over time. Next, a baseline must be established. This requires a significant amount of data-taking before any conclusions can be reached. Once the data have appeared to settle out, the system can be said to be "in control", meaning that the excursions of individual points from the statistical Mean are reasonably predictable. At this point, performance of the Metrics should be visually and prominently displayed so that unexplainable excursions will be immediately obvious, and can trigger corrective action.

After a great deal of investigating and baselining, we have been able to identify a single Metric for each Task area, allowing us to track effectiveness and detect anomalies quickly. These are generally related to turnaround times or data throughput.

4.6. Point 6. Institute Training. (People can't do their jobs well unless someone shows them how.) This means planned and structured training. Usually, when a tool or capability is being delivered to Operations, if a cost or schedule overrun occurs the first thing to be cut is Training. (The second thing to go is Documentation). The Operators are then left to learn on the fly, or not at all, the best way to operate. Operations Management must have a coherent training plan and must be empowered to pursue it through good and bad budgetary times. Associated with Training is Certification. The customer has a right to expect that critical systems and events will be controlled only by people who have demonstrated their competence.

4.7. Point 7. Institute Leadership. (Leading consists of helping people to do a better job). One of the most valuable principles of TQM is the new Leadership model. Too often, we fall back on the traditions of the Military model of a distant, fault-finding authority figure. This may be the description of the boss we all grew up with, but it is flawed in serious ways. (For one thing, the workforce of the Nineties are far less patient with autocratic Leaders than most of us were.) It is now a well-established fact that collaboration and empathy are superior methods of leading any group, especially one with such a critical mission as ours.

In our local Mission Operations activity, both JPL and OAO Managers have worked to move toward a more mentor-oriented style. For example, we form multi-level Process Improvement teams, in which supervisors and operators serve as peers. This creates a sense of familiarity and empowerment on the part of the people on the line. We also promote from within whenever practical, so that in many cases our first-line Supervisors have recently been operators, and can identify directly with the working level problems. These and other such initiatives have paid off in better communications and more service.

4.8. Point 8. Drive Out Fear. (People need to feel secure to ask "dumb questions" and learn from mistakes). During the early days of Spacecraft Operations, a senior executive in a former company had a standard response when informed of any error in operations, i.e. "Who are you going to fire?" We waste a valuable resource when we cultivate a fear of being wrong. The Total Quality paradigm says that we should not bury our mistakes but learn as much as possible from them. We should encourage the most Junior console operator to ask the most Senior Analyst, "why are you doing that?"

4.9. Point 9. Break Down Organizational Barriers. (One Department's goals may cause trouble for another.) This could have been written with Space Operations in mind. All of us have lived through horror stories about barriers. One of the most recurring is the case in which Development builds something which Ops can't use, but doesn't find out about until far too late. How many of you have seen the six-stage cartoon of building a tree-swing? We need to find ways to see that Operations people, at the Console-operator level, are a genuine part of the Requirements Definition, Specification, Testing, and Acceptance of their vital tools.

Another area in which barriers need to be broken down has to do with inter-organizational rivalry. Progress in barrier breaking can often be made by grouping related Operational activities at the lowest possible organizational level. As layers increase, the time and hassle required to react increase exponentially.

At JPL, we are making strides toward involving Operators in planning for new systems, but accountability to Operations is still lacking. In addition, much more needs to be done to optimize organizations for effective operations.

4.10. Point 10. Eliminate Slogans, Exhortations, and Targets for the Workforce. (Let workers formulate their own slogans.) The greatest dangers to a permanent quality program are sloganeering and faddism. Most of us have lived through "zero-defects", "Value Engineering", and a host of other cure-alls, which faded away along with the banners outside the office entrance. Once our people sense our trust, they won't need slogans to perform. It will be intrinsic. We have found on our contract that an ounce of involvement is worth a ton of slogans. We have seen a high level of commitment to quality principles simply as a result of presenting people with opportunities for training, improvement projects, and general participation in the TQM program. In other words, Empowerment.

4.11. Point 11. Eliminate Numerical Quotas. (They are usually a guarantee of inefficiency and high cost.) This point has relevance to much of the Space Operations environment. Imagine that a Programmer is rated solely on the number of Lines of Code she produces in a day; or that an analyst is penalized at raise time if he delays transmitting more than one command out of a hundred sent. These quotas will totally obscure the systematic realities behind the effort, and be a formidable block to efficiency and perhaps even Mission Safety. A valuable adjunct to this point is Deming's "85-15 Rule". This says that 85% of what goes wrong is due to the system, and is totally outside the human component. It is not only unfair but morale-defeating to measure people against events and situations beyond their control. We should train ourselves to look for the Systematic problems first. It's simple statistics.

4.12. Point 12. Remove Barriers to Pride of Workmanship. (People are eager to do a good job and distressed when they cannot.) Deming stresses the importance of thinking through our policies, and our practices. Providing Operators with poor supervision, faulty systems, and poor visibility into overall program goals are examples of such barriers. Another TQM term which applies here as well: "Recognize and Celebrate". Nothing has more leverage than a well-placed recognition ceremony or bonus check by which a quality performer can be recognized among his and their peers.

On our JPL contract, OAO has moved partially away from Performance ranking through monetary recognition of teamwork and quality program support. We still have a distance to go, however. Questions still exist about how to compensate "teams" instead of individuals. We have seen positive results from our Award Fee sharing program, Employee of the Month and Year, and our annual performance bonus. Through these and other recognition methods, we have been able to leverage a relatively small amount of money into a highly visible and effective program for improvement.

4.13. Point 13. Institute a Vigorous Program of Education and Retraining. (Both management and the workforce will have to be educated.) Total Quality may be only common sense, but it is frequently not intuitive. In order to reach any real level of improvement, both learning and "unlearning" must occur over a broad front. Here at JPL, as well as other centers, a great deal of commendable effort has already been expended in retraining staff at all levels to the new Quality paradigm. In Operations, we must make special efforts to move key people off the consoles and into classrooms, then follow up with practical training at their workplace. We have found that Process Improvement projects, initially under the guidance of specially-trained Facilitators, is an excellent way of validating the classroom training.

On our JPL contract, OAO has appointed Quality Subcommittees in each major line organization. In Mission Operations, this subcommittee has been trained, and is now involved in defining candidate processes for improvement projects. It is convened at least monthly by the Manager for general discussion and work on activities under way.

4.14. Point 14. Take Action to Accomplish the Transformation. (A critical mass of people must support the goal.) This point really summarizes the necessity of doing the other thirteen points right. One truth has been found wherever a Total Quality Program has been tried, e.g.: It takes more than a few “missionaries” to make TQM work. While a few may catch the vision first, there is no point in trying to achieve any real results without “selling” the program to the workforce at large. The good news is that the process is contagious. Even cynics begin to see the benefits of the program once it is underway. It is also a proven fact that TQM will not work without top-level support. Unless the people with real power are behind it, it will fail.

In large measure, the success of the MACS contract’s Program has been due to the active leadership of senior JPL and OAO management who support its goals with their continued attention, tough questions, and the necessary financial and human resources.

5. RESULTS ON THE JPL/OAO CONTRACT

Since assuming responsibility for the MACS Contract, OAO has submitted and had approved for Award Fee consideration, over 100 Process Improvement initiatives. These have resulted in cost savings to the Government of over \$9 Million , to which can be added numerous examples of improved processes and enhanced mission reliability. As a result , OAO has earned an additional \$1.3 Million in Profit, a significant percentage of which we have shared with our employees. And through this unique partnership, we have created an environment in which all parties have a reason to share in the bright future offered by Total Quality Management.

6. CONCLUSION

Based on personal experience gained in JPL Mission Operations, as well as the documented success stories wherever it has been tried, I am convinced that TQM can be a valuable tool for Spacecraft Operations. It can provide us with a valuable vantage point from which to achieve greater effectiveness, and thus greatly assist in reversing the operations cost trends without introducing additional mission risk.

7. REFERENCES

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