The emerging world economy presents challenges to all industrial nations in productivity, product reliability and customer confidence level. The challenges are being met in various nations by reorienting industries for the production and marketing of "world class" products. Such reorientation requires significant cultural changes, significant improvements in management and judicious implementation of new and developing technologies. Reorientation to "world class" production has been implemented in the United States of America by a Department of Defense initiative that is known as "Total Quality Management or TQM".

An overview of the essential elements of TQM, some of the tools, considerations for implementation and descriptions of successful applications was presented in a forum address by Dr. Toru Iura. Dr. Iura's presentation included both background history of quality management; the transition from the Deming management principles to focus on requirements of the technical processes; and the culture changes required to manage the technical processes and value-added process steps. His presentation was followed by a brief discussion of TQM initiatives and experiences in various industries and by an interactive audience / panel discussion on the QNDE role in TQM initiatives. Major elements of Dr. Iura's presentation are included in the viewgraphs herein.
What Is Quality?

- QUALITY IS MEETING THE CUSTOMER'S NEEDS OVER THE LIFE OF THE PRODUCT
- IT HAS MANY DIMENSIONS
  - RELIABILITY
  - MAINTAINABILITY
  - PERFORMANCE
  - DURABILITY
  - CONFORMANCE (to requirements)
- IT IS NOT TO BE CONFUSED WITH LUXURY FEATURES

Evolution of Quality Management Awareness

**ORIGINS**
- DEMING
  - STATISTICAL CONTROL
  - QC MANAGEMENT PHILOSOPHY
- JURAN
  - PROJECT APPROACH
- DRUCKER
  - PLANNING/MARKETING

**JAPANESE DEVELOPMENTS**
- JUSE /ASHIKAWA
  - TOTAL INDUSTRY INVOLVEMENT
  - NATIONWIDE QC PROMOTION
- KAIZEN STRATEGY
  - CONTINUOUS IMPROVEMENT
  - PROCESS ORIENTATION

**RECENT U.S. INDUSTRY ADAPTATIONS**
- COMPANYWIDE QUALITY EXCELLENCE INITIATIVES
- INTRODUCTION OF PROVEN JAPANESE TECHNOLOGIES IN QUALITY MANAGEMENT
- DEPARTMENT OF DEFENSE ACTIONS
  - TOTAL QUALITY MANAGEMENT (TQM) POLICY
  - R&M 2000 VARIABILITY REDUCTION PROCESS (VRP)

*UNION OF JAPANESE SCIENTISTS AND ENGINEERS*
Deming’s Fourteen Points

1. CREATE CONSTANCY OF PURPOSE FOR IMPROVEMENT OF PRODUCT AND SERVICE
2. ADOPT THE NEW PHILOSOPHY
3. CEASE DEPENDENCE ON MASS INSPECTION
4. END THE PRACTICE OF AWARDING BUSINESS ON PRICE TAG ALONE
5. IMPROVE CONSTANTLY AND FOREVER THE SYSTEM OF PRODUCTION AND SERVICE
6. INSTITUTE TRAINING
7. INSTITUTE LEADERSHIP
8. DRIVE OUT FEAR
9. BREAK DOWN BARRIERS BETWEEN STAFF AREAS
10. ELIMINATE SLOGANS, EXHORTATIONS, AND TARGETS FOR THE WORKFORCE
11. ELIMINATE NUMERICAL QUOTAS
12. REMOVE BARRIERS TO PRIDE OF WORKMANSHIP
13. INSTITUTE A VIGOROUS PROGRAM OF EDUCATION AND RETRAINING
14. TAKE ACTION TO ACCOMPLISH THE TRANSFORMATION

Deming Point 3

- CEASE DEPENDENCE ON INSPECTION TO ACHIEVE QUALITY

• UNDERSTAND THE PURPOSE OF INSPECTION, FOR IMPROVEMENT OF PROCESSES AND REDUCTION OF COST
Progress in Quality Assurance Methods

**EVOLUTION OF QUALITY ASSURANCE METHODS IN JAPAN**

<table>
<thead>
<tr>
<th>PERCENT CONTRIBUTION TO QUALITY</th>
<th>0%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
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<tbody>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1960</td>
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<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0%</td>
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*SOURCE: L.P. SULLIVAN, AMERICAN SUPPLIER INSTITUTE*

**COST REDUCTIONS FROM NEW QUALITY ASSURANCE METHODS**

*SOURCE: USAF/LE-RD*

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**Elements of a Total Quality Management Program**

**GUIDING PRINCIPLES**
- QUALITY FIRST
- CUSTOMER SATISFACTION
- CONTINUOUS IMPROVEMENT
- MANAGEMENT COMMITMENT
- EMPLOYEE INVOLVEMENT
- SUPPLIER PARTICIPATION

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**OVERALL CONCEPTS**
- SIMULTANEOUS ENGINEERING
- VARIABILITY REDUCTION
- QUALITY FUNCTION DEPLOYMENT
- PARAMETER DESIGN
- DESIGN OF EXPERIMENTS
- STATISTICAL PROCESS CONTROL
- COMPANYWIDE TRAINING

**PRODUCT DESIGN APPROACHES**
- DESIGN/BUILD TEAMS
- DESIGN SIMPLIFICATION
- MODULAR CONSTRUCTION
- COMPUTER-AIDED ENGINEERING (CAE)
- EXISTING DESIGN UTILIZATION

**MANUFACTURING TECHNIQUES**
- JUST-IN-TIME (JIT)
- AUTOMATION/ROBOTICS
- CELLULAR MANUFACTURING
- TOTAL PRODUCTIVE MAINTENANCE (TPM)
- IN-PROCESS CONTROL
- COMPUTER-INTEGRATED MANUFACTURING (CIM)
Traditional U.S. Approach to Quality
MAKE IT TO SPECIFICATIONS

Select an Area or Process

PLAN the Change

DO the Change

CHECK the Change

P-D-C-A

Traditional U.S. Approach to Quality
MAKE IT TO SPECIFICATIONS

<table>
<thead>
<tr>
<th>LOSS ($)</th>
<th>NO GOOD</th>
<th>GOOD</th>
<th>NO GOOD</th>
</tr>
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<tbody>
<tr>
<td>LSL</td>
<td>(TARGET)</td>
<td>USL</td>
<td></td>
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</tbody>
</table>

(LOWER SPECIFICATION LIMIT) (UPPER SPECIFICATION LIMIT)
True Impact of Product Variability

(LOSS FUNCTION)

• LOSS FUNCTION - DOLLAR LOSS DUE TO DEVIATION
  OF PRODUCT FROM "IDEAL" CHARACTERISTIC
  - DIMENSION
  - SURFACE FINISH
  - ELASTICITY
  - GAIN
  - OTHER

• SOURCES OF LOSS
  - SCRAP
  - REWORK
  - WARRANTY OBLIGATIONS
  - DECLINE OF REPUTATION
  - FORFEITURE OF MARKET SHARE

• LOSS CHARACTERISTIC IS CONTINUOUS - NOT
  A STEP FUNCTION

Variability Reduction

• VARIABILITY REDUCTION IS A MODERN CONCEPT OF DESIGN AND
  MANUFACTURING EXCELLENCE
  - REDUCING VARIABILITY AROUND THE TARGET VALUE LEADS TO
    BETTER PERFORMING, MORE UNIFORM, DEFECT-FREE PRODUCT
  - VIRTUALLY ELIMINATES REWORK AND WASTE

CONTINUOUSLY IMPROVE PRODUCT QUALITY BY REDUCING VARIABILITY
Process Capability Relationships

PROCESS CAPABILITY IS THE RATIO OF SPECIFICATION RANGE TO PROCESS RANGE

<table>
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<tr>
<th>PROCESS CAPABILITY (Cp)</th>
<th>PPM DEFECTIVE</th>
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<tr>
<td>0.60</td>
<td>71,800</td>
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<tr>
<td>1.33</td>
<td>66</td>
</tr>
<tr>
<td>1.67</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4.50</td>
<td>&lt;&lt;1 PPB</td>
</tr>
</tbody>
</table>

Ford Experience in Variability Reduction

- SPECS AND BLUEPRINTS OF NEW TRANSAXLE GIVEN TO BOTH FORD (USA) AND MAZDA (partially owned by Ford)

- TRANSAXLES FROM BOTH PLACES FELL WITHIN SPECIFICATION AND PERFORMED WELL, BUT MAZDA TRANSAXLE WAS SUPERIOR (drove more smoothly)

- BREAKDOWN REVEALED
  - JAPANESE PRODUCT HAD FINER FINISH, FEWER CHIPS AND BURRS, LESS VARIATION

- MAZDA HAD MADE THEIR PRODUCT CLOSER TO TARGET VALUE
  - PROCESS RANGE WAS 27 PERCENT OF SPECIFICATION RANGE, COMPARED TO 70 PERCENT FOR FORD

- FORD NOW SPECIFIES TARGET VALUES AND HAS IMPLEMENTED VARIABILITY REDUCTION APPROACH

Key TQM Techniques

- SIMULTANEOUS ENGINEERING
- QUALITY FUNCTION DEPLOYMENT (QFD)
- PARAMETER DESIGN
- STATISTICAL TOOLS
Simultaneous Engineering

- A NEW APPROACH TO ENGINEERING THE PRODUCT
- ADDRESSES CONCURRENTLY, EARLY IN THE DESIGN STAGE:
  - ALL PRODUCT PERFORMANCE CHARACTERISTICS
  - ALL PRODUCTION PROCESS FACTORS
  - ALL OPERATIONAL ISSUES
- IMPLEMENTED BY THE USE OF PRODUCT DEVELOPMENT TEAMS WITH ALL PERTINENT DISCIPLINES REPRESENTED
- REDUCES DEVELOPMENT LEAD TIME AND COST

PERSONNEL INTERACTION AND CONTINUOUS COMMUNICATION ARE ESSENTIAL

Quality Function Deployment (QFD)

- QFD IS A SYSTEMATIC METHODOLOGY FOR TRANSLATING THE "VOICE OF THE CUSTOMER" INTO DESIGN CHARACTERISTICS AND TARGET VALUES THAT ARE DISSEMINATED TO ALL PROJECT PERSONNEL
- FIRST USED IN 1972 AT MITSUBISHI'S SHIPYARD IN KOBE, JAPAN, A ONE-OF-A-KIND OPERATION
- IT EMPHASIZES EARLY PARTICIPATION OF ALL DISCIPLINES IN PRODUCT DEVELOPMENT DELIBERATIONS AND DECISIONS
  - PROVIDES FRAMEWORK FOR SIMULTANEOUS ENGINEERING ACTIVITIES
  - FACILITATES CROSS-FUNCTIONAL COMMUNICATIONS

Quality Function Deployment Procedure

- QFD USES A STRUCTURED FORMAT OF SEQUENTIAL MATRICES WHICH PROVIDE GUIDANCE IN CONVERTING THE CUSTOMER'S REQUIREMENTS INTO THE MANUFACTURED PRODUCT

Diagram: Quality Function Deployment Procedure

CUSTOMER REQUIREMENTS

PRODUCT PLANNING

PART CHARACTERISTICS

MANUFACTURING REQUIREMENTS

PROCESS PLANNING

PRODUCTION OPERATIONS

PRODUCTION PLANNING

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Benefits of Quality Function Deployment

- Identifies critical characteristics and conflicting design requirements
- Decreases number of engineering changes
- Results in fewer process start-up problems
- Reduces product development time while improving quality and lowering cost
- Documents design rationale for future reference

NEW vs CONVENTIONAL APPROACH TO RESOLUTION OF PROBLEMS

Parameter Design
STEPS IN PRODUCT/PROCESS OPTIMIZATION

OFF-LINE QUALITY CONTROL
ENGINEERING OPTIMIZATION USING DESIGN OF EXPERIMENTS

PRODUCT DESIGN

PROCESS DESIGN

SYSTEM DESIGN INNOVATION

PARAMETER DESIGN OPTIMIZATION

TOLERANCE DESIGN OPTIMIZATION

ON-LINE
QUALITY CONTROL
PROCESS CONTROL IN PRODUCTION

SOURCE: L. SULLIVAN
AMERICAN SUPPLIER INSTITUTE
Parameter Design (Cont'd)

- A SYSTEMATIC APPROACH TO MAKING A PRODUCT ROBUST; I.e., so that it has minimal sensitivity to influential process and use factors

- INFLUENTIAL FACTORS CONSIST OF:
  - CONTROL FACTORS -- VARIABLES EASILY CONTROLLED SUCH AS PROCESS SETTINGS
  - NOISE FACTORS -- VARIABLES DIFFICULT TO CONTROL SUCH AS CUSTOMER USE CONDITIONS

- PARAMETER DESIGN SEEKS TO FIX CONTROL FACTORS AT VALUES WHICH MAKE THE PRODUCT INSENSITIVE TO NOISE FACTORS

- DETERMINING BEST PRODUCT PERFORMANCE RELATIVE TO ALL POSSIBLE FACTOR COMBINATIONS GENERALLY INVOLVES AN EXCESSIVE NUMBER OF TESTS
  - NUMBER OF TESTS CAN BE REDUCED BY USING DESIGN OF EXPERIMENTS APPROACH

Taguchi Case Study Summary*

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>PRODUCT</th>
<th>WHAT WAS DONE</th>
<th>RESULTS</th>
</tr>
</thead>
</table>
| AEROJET ORDNANCE COMPANY | PYROTECHNICS | DATA BASE ESTABLISHED FOR FUTURE DESIGNS WITH ONLY 24 EXPERIMENTS (3 MAN-MONTHS). FULL FACTORIAL EXPERIMENTS WOULD HAVE REQUIRED 800 MM | • REDUCED DEFECT RATE ON TRACER PELLETS TO ZERO
|                    |              |                                                                               | • COST SAVINGS $560 MILLION                                           |
| BOSCH CORPORATION  | FUEL PUMP    | 12 EXPERIMENTS TO FIND PARAMETER VALUES FOR REDUCING DEFECTIVE COLD-STARTS (420 MAN-HOURS) | • REDUCED DEFECT RATE FROM 40% TO LESS THAN 1%
|                    |              |                                                                               | • ESTIMATED SAVINGS OF $1,081,000                                    |
| ITT INTERMETALL    | IC CHIPS     | MAXIMIZED BOND STRENGTH AND INCREASED BONDING YIELD WITH 18 EXPERIMENTS (50 MAN-HRS) | • YIELD IMPROVEMENT RESULTED IN 20,000 DZ/YR SAVINGS
|                    |              |                                                                               | • BOND STRENGTH INCREASED 20%
|                    |              |                                                                               | • VARIANCE REDUCED BY 4                                               |

*REFERENCE: AMERICAN SUPPLIER INSTITUTE, FIFTH SYMPOSIUM (1987)
Planning and Problem Solving Tools

PARETO

CUMULATIVE COST IMPACT

PROBLEM

ISHIKAWA (fishbone)

MEASUREMENT

METHOD

MAN

MACHINE

MATERIAL

PROBLEM

PRIORITIZES PROBLEMS

LINKS CAUSE AND EFFECT

Cultural Changes Needed

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
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<tbody>
<tr>
<td>BOTTOM LINE EMPHASIS</td>
<td>QUALITY FIRST</td>
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<tr>
<td>MEET SPECIFICATION</td>
<td>CONTINUOUS IMPROVEMENT</td>
</tr>
<tr>
<td>GET PRODUCT OUT</td>
<td>SATISFY CUSTOMER</td>
</tr>
<tr>
<td>FOCUS ON PRODUCT</td>
<td>FOCUS ON PROCESS</td>
</tr>
<tr>
<td>SHORT TERM OBJECTIVES</td>
<td>LONG TERM VIEW</td>
</tr>
<tr>
<td>DELEGATED QUALITY RESPONSIBILITY</td>
<td>MANAGEMENT-LED IMPROVEMENT</td>
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<tr>
<td>INSPECTION ORIENTATION</td>
<td>PREVENTION ORIENTATION</td>
</tr>
<tr>
<td>PEOPLE ARE COST BURDENS</td>
<td>PEOPLE ARE ASSETS</td>
</tr>
<tr>
<td>SEQUENTIAL ENGINEERING</td>
<td>SIMULTANEOUS ENGINEERING</td>
</tr>
<tr>
<td>MINIMUM COST SUPPLIERS</td>
<td>QUALITY PARTNER SUPPLIERS</td>
</tr>
<tr>
<td>COMPARTMENTALIZED ACTIVITIES</td>
<td>COOPERATIVE TEAM EFFORTS</td>
</tr>
<tr>
<td>MANAGEMENT BY EDICT</td>
<td>EMPLOYEE PARTICIPATION</td>
</tr>
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</table>

MANAGEMENT COMMITMENT IS THE KEY

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TQM Impact on NDE

- LESS EMPHASIS ON END-OF-LINE INSPECTION

- GREATER INVOLVEMENT IN THE UPSTREAM DESIGN PROCESS
  - PARTICIPATE IN PRODUCT DESIGN TEAMS
  - LOOK FOR MORE EFFECTIVE USE OF NDE TECHNIQUES IN THE PRODUCT LIFE CYCLE
  - BUILD TESTABILITY INTO THE DESIGN

- GREATER EMPHASIS ON IN-PROCESS INSPECTION
  - LOOK FOR SIMPLE AND RELIABLE TECHNIQUES
  - INTEGRATE NDE WITH STATISTICAL PROCESS CONTROL

CHALLENGE: TO FIND INNOVATIVE APPLICATIONS OF NDE THAT ARE PROACTIVE, NOT REACTIVE
SYNOPSIS OF PANELISTS COMMENTS

Dr. Panhuise - Garrett Engine Division

The TQM initiative was integrated as an essential element of "world class" competitive posturing by the Garrett Engine Division. Key elements of success have been a proactive management team, open communications and vigorous training in the tools of TQM and innovative, team driven improvements. TQM has aided the Garrett Engine Division in gaining recognition for both improved quality in the local community and for innovation in the gas turbine industry.

Dr. Pettit - Lockheed Aero Systems Company

The Lockheed Aero Systems Company developed and organized its "Composites Development Center" to provide focus on process understanding and continuous process improvement. Traditional, functional organizational structure was set aside to manage the technical process by focus on teamwork strengths and capabilities by developing "value added" production capabilities. This mode of organization evolved from the notable "Lockheed Skunkworks" which earned both the respect and admiration of the aerospace industry. Innovative, adaptive and knowledge driven team players are the hallmarks of this operation and of the TQM initiative.

Dr. Bunting - Martin Marietta Astronautics Group

TQM is a total Martin Marietta organizational initiative and has been an all encompassing tool in new product development for the United States Air Force, Advanced Launch System (ALS). TQM demands changes in culture. Such changes are not realized as direct, straight line functions, but by exploration and divergence along the path. This is consistent with the culture of the American people who elected Jimmy Carter and Ronald Reagan back to back.

Teamwork is the hallmark of TQM. The success of team initiatives is highly dependent on the skill level of the team members in technical processes; ie. success is not formula or recipe based, but is knowledge based (work smarter, not harder). Teamwork is currently not emphasized in our educational curricula and is developed as a part of industrial experience. TQM provides an opportunity for skill broadening, multiple skill options and job security by innovation and organizational success.

TQM has been of significant value identifying innovative options for the ALS program and has been incorporated into long range planning, continuous process improvements and technology implementation on major Martin Marietta projects.
OPEN DISCUSSION

Q. Is TQM another "Zero Defects" program; ie. Hoopla without substance?

A. TQM is an initiative focused on a recognized challenge. It is not a substitute for good management. Indeed, it focuses on the examination of management as a primary premise.

Q. TQM focuses on cost reduction. What about jobs that are lost?

A. TQM requires cultural change at all levels for improvements in productivity, management and technology implementation. Improvements are required to preserve jobs. Teamwork in organizational management, training and individual skill development are necessary to make transitions to new (need defined) jobs.

Q. Equity in compensation is of concern in "redefined jobs". What is being done?

A. Cultural / structural changes must include compensation, promotion and accounting systems. Failure to align compensation with changes in culture will decrease and/or defeat the required cultural changes.

Q. What are the "accountants" doing for productivity improvement?

A. TQM must involve total organizational culture change. Non-value added "support" activities constitute the largest percentage of production costs. Although it is easier to analyze and identify improvements in processes that produce a tangible product, "support" operations may be analyzed in terms of processes completed to meet a customer need. "Functional" analysis of many "support" operations has identified many opportunities for cost reduction and overall productivity improvements. Zero based budgeting and "value added" analysis of "support activities" will often produce startling results. Total commitment to culture change is necessary for success. Customer involvement may be necessary to identify and rank needs. When the cost of providing lesser needs are recognized, customer assessment of value may result in significant reductions in "support activities".

Q. NDE is often applied as an inspection process (management process). Deming proposes elimination of inspection. What is the role of NDE?
A. Deming proposes to "cease dependence on mass inspection". NDE is often applied at the end of the line to "sort" acceptable products. If the results of an NDE measurement are used to improve or control a process, it is indeed a process control / sensor output and must be viewed as an integral part of process control and process improvement. TQM focuses on technical processes, of which NDE is a part. A TQM challenge is to provide judicious NDE measurements to decrease process variability. Considerable growth is needed in the integration of NDE measurements with statistical process control methods.

NDE will continue to be a vital tool for in-process and fitness for purpose acceptance in those cases where:

* Design parameters / margins and acceptance limits are not well understood (ie. new and/or innovative designs);
* Process parameters and process limits are not well understood or controlled (ie. limited production runs);
* Economics may favor final acceptance versus in-process measurements (ie. high confidence level in acceptance through in-line process control);
* Critical safety, sensitive high-value or functionally critical systems; and
* Requalification of "fitness for purpose during periodic or demand maintenance.

Indeed as emphasis in technical process understanding and process improvements are increased, the demand for NDE at all production levels will increase.

SUMMARY

TQM focuses on technical processes. The TQM initiative for continuous process improvement requires an improved and/or renewed understanding of the process parameters, processing steps, and boundary limits of control that result in process variance. Indirect measurement of process parameters by NDE methods may often provide the key to process understanding and process improvement. No process improvement can be effected unless process parameters are measured, analyzed and action taken. Variance reduction often imposes the requirement for quantitative NDE measurements and NDE measurement understanding. QNDE is both supportive and integral to the TQM initiative and to overall improvements in product, system and structures reliability and confidence level.

* The QNDE Topical Forum is a traditional event at the annual QNDE conference to provide discussion and interchange on topics that impact, and are of timely interest to the QNDE community.

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