# The Role of Metrics and Measurements in a Software Intensive Total Quality Management Environment.

**Charles B. Daniels**
**Paramax Space Systems**
**595 Gemini Avenue**
**Houston, Texas 77058**

**December 2, 1992**

## 1. Background

Paramax Space Systems began its mission in 1986 as a member of the Rockwell Space Operations Company (RSOC) team which was the successful bidder on a massive operations consolidation contract for the Mission Operations Directorate (MOD) at the Johnson Space Center (JSC). The contract awarded to the team was the Space Transportation System Operations Contract (STSOC). Our initial work force consisted of less than twenty people. We staffed the contract with employees from the unsuccessful incumbent contractors. Our initial challenge was to accept responsibility for a very large, highly complex and fragmented collection of software from eleven different contractors and transform it into a coherent, operational baseline. Concurrently, we had to integrate a diverse group of people from eleven different companies into a single, cohesive team. Paramax executives recognized the absolute necessity to develop a business culture based on the concept of employee involvement to execute and improve the complex processes of our new environment. Our executives clearly understood that management needed to set the example and lead the way to quality improvement. One of our first acts as a management team was to develop, document and display our quality policy, which states:

- We shall strive for excellence in all endeavors.

- We shall set our goals to deliver error-free products and services on time.

- We shall understand and conform to the requirements.

- We shall understand the software processes associated with our jobs.

- We shall measure our performance in terms of satisfying the requirements.

- We shall analyze failures and take corrective action to prevent their recurrence.

All executives and managers signed this pledge. It is posted throughout the various buildings, including several at JSC, where our employees work.

## 2. Paramax Space Systems Operation Spaceflight Role

Paramax Space Systems supplies $78 million of software products and services annually for the Space Shuttle and Space Station programs at the Johnson Space Center and projects at the GSFC. Our current major projects include the following.

- Space Shuttle and Space Station Freedom operations
- Mission Control Center upgrades
- Space Station Control Center development
- Software product and quality assurance at JSC

- Space Shuttle preflight evaluation
- Information Systems support
- Quality engineering and quality assurance at GSFC

Space Systems manages, modifies and maintains all ground-based software for the Space Shuttle program. We provide products and services for all phases of Shuttle operations, including flight design and mission planning; astronaut and flight controller training; preflight and postflight verification of orbiter software, systems and components; and real-time command, control and communications in JSC's Mission Control Center.

This is, to the best of our knowledge, the largest, most complex scientific/technical software project in the world. Our work at JSC encompasses 19 million lines of code written in 15 programming languages and running on more than 300 computers in 13 facilities. This is truly a massive task.

At the Goddard Space Flight Center, we provide quality engineering and quality assurance for Earth-observing and scientific satellites. We also evaluate the safety, reliability and quality of electronic, mechanical and other components, and calibrate and repair testing equipment.

Paramax Space Systems employs more that 1,000 people at its Houston location and more that 250 people in Lanham, Maryland.

## 3. Focus of our Quality Management Effort

Our commitment to the quality process is articulated in our quality policy. Our commitment to our customers is to achieve increasing levels of reliability, productivity and responsiveness. The software we maintain is a critical component in the safety and mission success of Space Shuttle missions. Safety, of course, is our first concern. We continually strive to improve the productivity of our software engineering processes to support NASA's worthy goals to establish a permanent presence in space, on the Moon and on Mars. The nature of manned spaceflight demands our immediate response to identify and correct failures, and ensure they never recur.

We achieve our goals through the commitment of our management team to the quality process, their emphasis on involving all of our employees in improvement teams, and the use of metrics and measurements to manage our business.

## 4. Management Commitment

Paramax management is visibly and actively involved in every aspect of our quality process. Managers and executives provide leadership through our quality infrastructure, participate in our quality education process, and work hand-in-hand with our Excellence Teams to foster total organizational involvement and cross-functional teamwork. Our managers address quality topics as a regular agenda item in staff meetings to ensure ongoing awareness of the need for continuous improvement. Paramax also establishes quality improvement goals as an integral part

of our annual strategic planning process. All our annual organizational goals have a quality orientation. Quality goals are included in each manager's annual performance plan, and we are beginning to establish role model standards to measure and improve our leadership processes.

## 5. Employee Involvement through Team Excellence

Management commitment is the foundation of our quality effort, but significant improvement is not possible without the active involvement of all employees. At Paramax, this is accomplished through the Team Excellence process.

Our work force is divided into functional Centers of Excellence, each represented by an Excellence Team composed of management and employees. Excellence Teams represent work groups at every level of the organization. Each Excellence Team is required to:
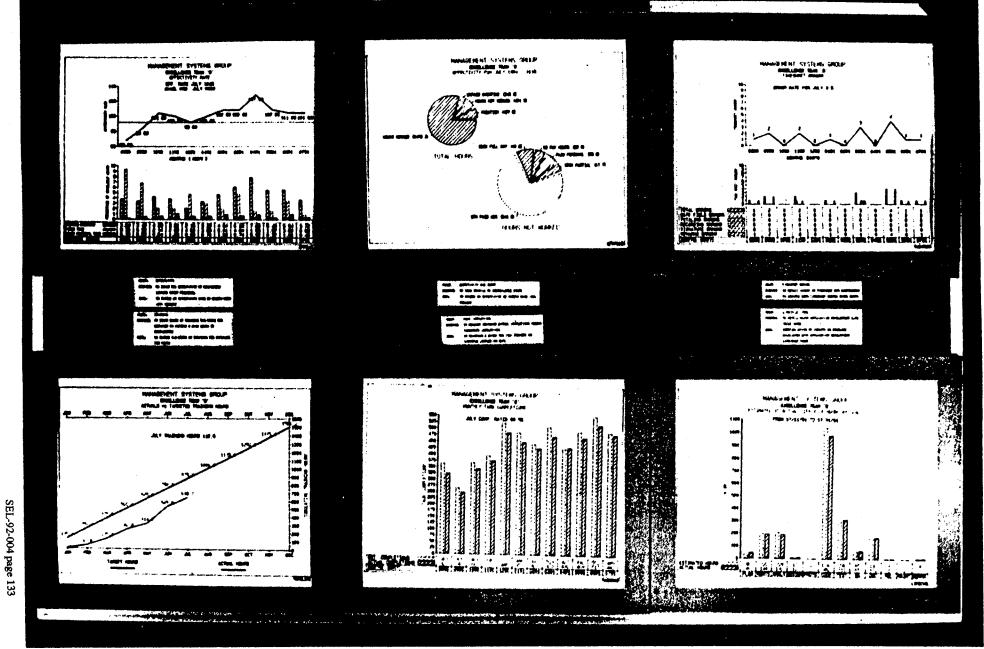
- identify and document the processes under their direct control;
- establish metrics and measurements to monitor the processes;
- initiate corrective action and process improvement; and
- publicly post the results on the team bulletin board in the team work area.

Initially, Team Excellence board requirements were established by the Paramax Quality Improvement Team and included the following elements.

- Team Mission Statement
- Team Goals
- Procedure Reference
- Team Members
- Visitor's Log

As this activity evolved, teams developed more sophisticated Excellence Board criteria. Excellence Teams are currently evaluated on a quarterly basis according to specific criteria. The purpose of the evaluation is to ensure the continued effectiveness of Excellence Teams. Special recognition is provided for teams who achieve a perfect score on the evaluation, and all teams are honored annually for their contributions to the organization. The Team Excellence bulletin boards have created a "window" into the daily operation of each team and have involved every employee in the improvement process. The boards are a forum for each team to showcase their efforts and accomplishments. Team goals are publicly displayed, as are the accompanying process metrics. Examples of Team Excellence boards are depicted in figure 1 through figure 5.

# TEAM EXCELLENCE

Figure 1 - Team Excellence Primary Metrics Board

# TEAM EXCELLENCE

**UNISYS**
Houston Operations

**Training and Planning Software**

Figure 2 - Team Excellence Secondary Metrics Board

Figure 3 - Team Excellence Process Improvement Board

Figure 4 - Team Excellence Recognition Board

Figure 5 - Team Excellence Quick Victories Board

## 6. The Measurement Process

The significant successes we have enjoyed are direct results of our quality efforts. A major element of these achievements is our emphasis on a data-driven, decision-making process. We use a structured metrics development and deployment methodology to manage all our processes.

The initial step in an effective metrics development effort is to define the process. Until and unless a process has been defined, analyzed and documented, metrics and measurements can not be applied to monitor and improve it. Once process definition has been completed, a decision must be made concerning the process area most in need of improvement. The individuals and teams who work closely with the process, the implementors,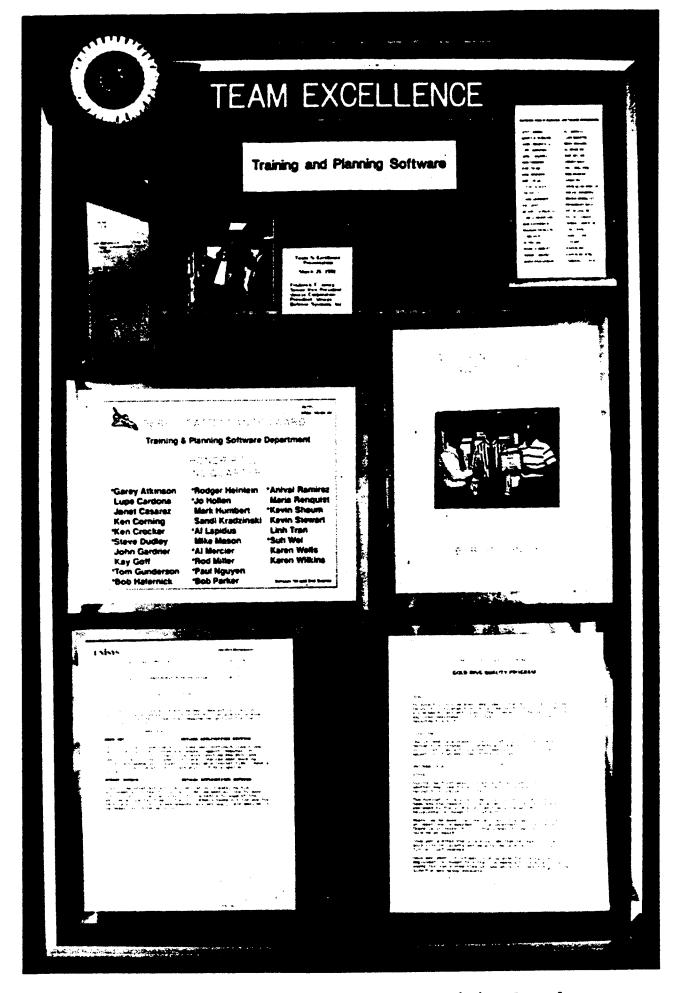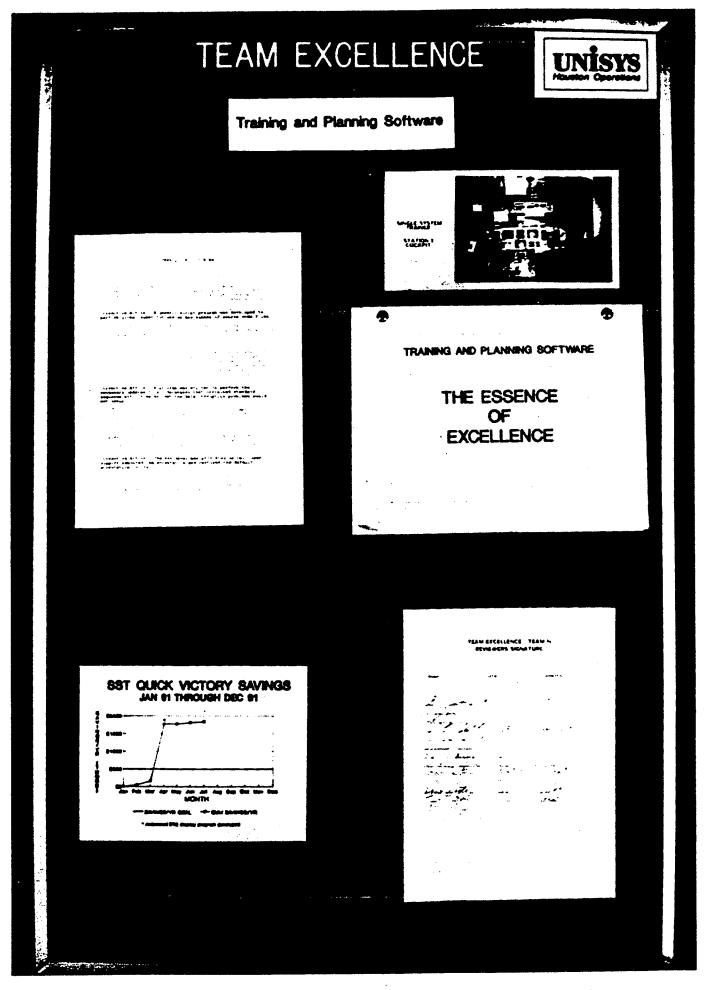 are best suited to determine how to measure the performance of the process. At this point, we are interested in performance of the process rather than the quality of the end product. While product quality is always significant, our goal in process analysis and measurement is first to improve the process itself; improvement in the end product will naturally follow.

The next step is to measure the process and establish an adequate data baseline. Several periods must be measured to ensure that a descriptive trend develops. Once the data has been measured and baselined, it must be evaluated to determine the state of the process. At this point, improvement objectives can be defined and action can be taken to improve the process. Decisions must be made by the team who implemented the process, the process improvement team (if another team) and management about improvement priorities. Pareto analysis, cost-benefit analysis and decision-support tools must be applied to ensure that scarce resources are effectively used in the improvement process. None of the tools can be applied until the state of process has been determined. Figure 6 provides an example of reevaluating commitments based on collecting and analyzing metrics. Once a process has been optimized, it may still be necessary to monitor progress to validate long-term stability.

## 7. Measuring Performance

When we establish metrics, we ensure they are easily collectible, unambiguous, meaningful, important, controllable and representative of the process being monitored. If any of these requirements is violated, it is necessary to evaluate the metrics to determine their relationship to the improvement objectives for the process. It is sometimes necessary to use a different measurement technique or different metrics to meet the defined improvement goals.

## 8. Standard Metrics

We have established standard metrics for each organizational element and Excellence Team. The metrics are collected in four categories.

- Quality Performance
- Workflow Performance
- Productivity Performance

●     Team-Building

The standard metrics set facilitates consistent communication within the organization and gives Paramax management a regular summary as well as long-term trend performance information about individual teams or the organization as a whole. The metrics are communicated through the organization by using the objectives matrix. Paramax standard metrics are displayed in figure 7.

## 9. The Objectives Matrix

The objectives matrix is a tool for summarizing measurement objectives and accomplishments. It is a method to record current performance, goals, the proportionate value of performance indicators and the rate at which improvement is made. The data can then be analyzed to determine trends and concentrate attention on areas requiring improvement. The objectives matrix can be used to measure a project, program or organization and can be "rolled up" to higher-level matrices. This is an exceptional tool to understand and monitor the health and status of an organization. An objectives matrix is displayed in figure 7-1.

# 1991 Performance on New Commitments

| Criteria | Performance | Goal |
|---|---|---|
| **Satisfiers** | Range | |
| SR closure to receipt ratio | .99 | 1.0 |
| DR closure to receipt ratio | 1.01 - 1.09 | 1.0 |
| Milestones met | 87 - 99% | 100% |
| Labor hours per SR | 232 - 358 | 170 |
| Resource allocation for SRs | 24 - 25.5% | 32% |
| Resource allocation for Engineering | 50.0 - 53.3% | 64% |
| Engineering productivity (KLOC per Engineer) | 40.0 - 41.8 | 44 |
| Monthly process improvements | 79 - 122 | 76 |
| Team effectiveness | 99.23 - 100.07% | 100% |
| Training hours/employee/month | 2.0 - 2.58 | 4.0 |
| **Dissatisfiers** | | |
| SR backlog | 1283 - 1314 | <1000 |
| DR backlog | 1290 - 1342 | <1000 |
| Process failures | 126 - 129 | 0 |
| Mean-time-to-fix, critical problems | 18 - 20 days | 13 |
| Mean-time-to-fix, all problems | 102 - 122 days | 30 |
| Attrition rate | 5.17 - 7.78% | < 9.5% |

Figure 6

## Team Excellence Inputs

| Department | 1251 | 1252 | 1253 | 1254 | 1255 | 1256 | 1257 | 1258 | 1259 | 1353 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Derived Inputs** | | | | | | | | | | | |
| DR Labor Hours | 5692 | 2185 | 3785 | 356 | 1149 | 390 | 1206 | 420 | 0 | 19 | 13674 |
| SR Labor Hours | 9795 | 5643 | 16373 | 12007 | 13035 | 6229 | 3704 | 3556 | 1232 | 537 | 75568 |
| Release Labor Hours | 4400 | 885 | 3070 | 2240 | 419 | | 2238 | 1765 | 0 | 198 | 4201 |
| KLOC - Software Inventory | 3900 | 1529 | 2223 | 1011 | 4270 | 4895 | 2475 | 0 | 0 | 0 | 19503 |
| Staffing Overrun | Authorized H/C | 120 | 95 | 158 | 115 | 118 | 137 | 66 | 41 | 13 | 50 | 935 |
| (Paramax employees only) Actual H/C | 122 | 95 | 116 | 118 | 106 | 140 | 68 | 39 | 12 | 48 | 932 |
| Overrun % | 1.7 | 0.0 | -26.6 | 2.6 | -10.2 | 2.2 | 3.0 | -4.9 | -7.7 | -4.0 | -0.3 |
| Average Duration to Close | | | | | | | | | | | |
| # Critical DRs Closed | 0 | 0 | 11 | 4 | 1 | 2 | 1 | N/A | N/A | 0 | 19 |
| Avg Duration - Avg Time to Fix | 0 | 0 | 12 | 8 | 23 | 40 | 45 | N/A | N/A | 0 | 17 |
| # Major DRs Closed | 47 | 13 | 88 | 55 | 19 | 12 | 7 | N/A | N/A | 0 | 241 |
| Avg Duration | 86 | 153 | 128 | 53 | 25 | 405 | 133 | N/A | N/A | 0 | 110 |
| # Minor DRs Closed | 35 | 34 | 23 | 21 | 14 | 8 | 6 | N/A | N/A | 7 | 148 |
| Avg Duration | 59 | 169 | 145 | 29 | 20 | 872 | 146 | N/A | N/A | 53 | 137 |
| Composite DRs Closed | 82 | 47 | 122 | 80 | 34 | 22 | 14 | N/A | N/A | 7 | 408 |
| Composite Avg Duration - Avg Time to Fix | 74 | 165 | 121 | 44 | 23 | 542 | 0 | N/A | N/A | 53 | 115 |
| Work Item Backlog  DR Received | 66 | 36 | 135 | 106 | 33 | 12 | 20 | N/A | N/A | 4 | 333 |
| DR Closed | 86 | 47 | 128 | 88 | 36 | 22 | 14 | N/A | N/A | 7 | 349 |
| DR EOM Open | 198 | 103 | 502 | 134 | 26 | 116 | 122 | N/A | N/A | 4 | 1205 |
| SR Received | 18 | 9 | 25 | 37 | 17 | 22 | 5 | N/A | N/A | 7 | 103 |
| SR Closed | 12 | 7 | 23 | 35 | 29 | 33 | 7 | N/A | N/A | 3 | 139 |
| SR EOM Open | 159 | 76 | 299 | 489 | 146 | 363 | 118 | N/A | N/A | 58 | 1361 |
| Avg Age of Critical DRs | 0 | 0 | 93 | 5 | 0 | 52 | 10 | N/A | N/A | 0 | 36 |
| # Critical DRs | 0 | 0 | 1 | 2 | 0 | 2 | 1 | N/A | N/A | 0 | 6 |
| Avg Age of Major DRs | 99 | 69 | 273 | 62 | 64 | 480 | 339 | N/A | N/A | 0 | 230 |
| # Major DRs | 94 | 24 | 297 | 68 | 13 | 67 | 47 | N/A | N/A | 0 | 610 |
| Avg Age of Minor DRs | 125 | 127 | 380 | 50 | 37 | 731 | 339 | N/A | N/A | 68 | 278 |
| # Minor DRs | 104 | 79 | 204 | 64 | 13 | 47 | 74 | N/A | N/A | 4 | 589 |
| Avg Age of ALL DRs | 113 | 113 | 316 | 55 | 51 | 574 | 61 | N/A | N/A | 68 | 257 |
| **Department Inputs** | | | | | | | | | | | |
| 1st Level Milestones Available | 0 | 0 | 29 | 212 | 78 | 91 | 3 | N/A | N/A | 39 | 460 |
| Met | 0 | 0 | 25 | 209 | 77 | 91 | 3 | N/A | N/A | 39 | 452 |
| 2nd Level Milestones Available | 0 | 22 | 591 | 7 | 76 | 67 | 4 | N/A | N/A | 0 | 767 |
| Met | 0 | 21 | 590 | 7 | 75 | 67 | 4 | N/A | N/A | 0 | 764 |
| # Releases | 1 | 3 | 2 | 20 | 53 | 21 | 3 | N/A | N/A | 39 | 142 |
| # Prog / Engineers | 61 | 23 | 97 | 49 | 77 | 104 | 42 | N/A | N/A | 50 | 503 |
| # Personnel allocated to : DRs | 49 | 14 | 15 | 16 | 4 | 9 | 31 | N/A | N/A | 2 | 140 |
| Goal | 49 | 12 | 25 | 11 | 4 | 9 | 31 | N/A | N/A | 0 | 141 |
| : SRs | 12 | 9 | 58 | 28 | 55 | 95 | 11 | N/A | N/A | 2 | 270 |
| Goal | 12 | 11 | 32 | 30 | 56 | 95 | 11 | N/A | N/A | 5 | 252 |
| : Build / Test / Rel | 31 | 10 | 16 | 12 | 7 | 7 | 14 | N/A | N/A | 45 | 142 |
| Goal | 31 | 10 | 21 | 15 | 6 | 8 | 14 | N/A | N/A | 45 | 150 |
| # Failures in  Eng. Process | 3 | 0 | 8 | 4 | 15 | 0 | 7 | N/A | N/A | 0 | 37 |
| Req. Mgmt | 0 | 0 | 3 | 0 | 2 | 0 | 0 | N/A | N/A | 0 | 5 |
| Supplier Input | 0 | 0 | 45 | 3 | 1 | 0 | 0 | N/A | N/A | 0 | 49 |
| Post-Rel. Prod. | 3 | 0 | 0 | 1 | 22 | 0 | 0 | N/A | N/A | 0 | 26 |
| # Process Improv. Conducted | 36 | 3 | 2 | 8 | 11 | 3 | 0 | N/A | N/A | 0 | 63 |
| # Critical Skill W/O Backlog | 0 | 0 | 5 | 5 | 6 | 11 | 2 | N/A | N/A | 0 | 29 |
| # Staff Meetings | 10 | 30 | 60 | 34 | 33 | 53 | 20 | N/A | N/A | 30 | 271 |
| **Human Resources Input** | | | | | | | | | | | |
| # Personnel W/O UTQP after 90 days | 1 | 24 | 32 | 16 | 13 | 36 | 7 | 5 | 1 | 1 | 136 |
| Avg. Training Hours / person | 1.6 | 8.5 | 8.4 | 3..2 | 1.5 | 2.9 | 1.8 | 2.4 | 4.1 | 4.7 | 3.91 |
| # of Current PP&Es | 106 | 91 | 160 | 116 | -106 | 129 | 68 | 39 | 12 | 48 | 875 |
| # of Total PP&Es | 114 | 95 | 161 | 116 | 106 | 140 | 68 | 39 | 12 | 48 | 922 |
| % of PP&E complete | 92.98 | 95.79 | 99.38 | 100 | 100 | 92.14 | 100 | 100 | 100 | 100 | 94.90 |
| # of Total Terminations (YTD) | 2 | 2 | 2 | 4 | 3 | 3 | 2 | 0 | 2 | 0 | 22 |
| # of Total Employees | 114 | 95 | 161 | 116 | 106 | 140 | 68 | 39 | 12 | 48 | 922 |
| Annualized Total Attrition | 4.21 | 5.05 | 2.98 | 8.28 | 6.79 | 5.14 | 7.06 | 0.00 | 40.00 | 0.00 | 5.73 |
| # of New College Hires | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| # of Total New Hires | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| % of College New Hires | 0.00 | 0.00 | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 |
| **Finance & Administration** | | | | | | | | | | | |
| Total # of Time Sheets | | | | | | | | | | | 1093 |
| # of Time Sheets in Error | | | | | | | | | | | 75 |
| % of Time Sheets in Error | | | | | | | | | | | 6.8 |
| **Finance & Administration Control** | | | | | | | | | | | |
| Available Hours | 20026 | 18893 | 25785 | 20354 | 20557 | 25040 | 12046 | 7674 | 2536 | 9117 | 165838 |
| Hours Worked | 21403 | 17361 | 29327 | 21539 | 19735 | 26818 | 12813 | 6811 | 2302 | 9033 | 171124 |
| Team Effectiveness | 106.87 | 91.87 | 114.09 | 105.82 | 96.00 | 107.10 | 106.36 | 88.76 | 90.79 | 99.08 | 103.19 |

Figure 7 - SSO Standard Metrics

| ORGANIZATION: PARAMAX - Space Systems | | | Software Sustaining Engineering Performance | | | | | | | | | | | DATE: October, 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| John B. Munson | | | | | | | | | | | | | | Director, Technical Excellence: C.B. Daniels | | |

**OBJECTIVES MATRIX**

**Performance Levels**

| Criteria | How Measured | This Month | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Score | Weight | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DR Closure Index | Closure/Receipt Ratio | 1.06 | .85 | .90 | ●.95 | 1.00 | (1.05) | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 | 1.35 | 4 | 20 | 80 |
| SR Closure Index | Closure/Receipt Ratio | 1.60 | .80 | .85 | .90 | .95 | 1.00 | 1.05 | 1.10 | 1.15 | 1.20 | ●1.25 | (1.30) | 10 | 20 | 200 |
| Milestones Met | No. 1st Level Milestones Met (%) | 97.9 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | (97) | ●98 | 99 | 100 | 7 | 15 | 105 |
| SR Backlog | EOM Open SRs | 900 | 1500 | 1400 | 1300 | 1200 | 1100 | ●100 | (900) | 800 | 700 | 600 | 500 | 6 | 15 | 90 |
| DR Backlog | EOM Open DRs | 993 | 1500 | 1400 | ●1300 | 1200 | 1100 | (1000) | 900 | 800 | 700 | 600 | 500 | 5 | 10 | 50 |
| Critical DR Responsiveness | Mean Time to Fix Critical DRs | 14 | 25 | 23 | 21 | 19 | 17 | (15) | 13 | 11 ● | 9 | 7 | 5 | 6 | 10 | 50 |
| Critical DR Age | Average Age of EOM Open Critical DRs | 0 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | (24)● | 10 | 10 | 50 |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

Circle Current Month's Score  ○

Solid dot for Prior Month's Score  ●

| | |
|---|---|
| Current Month | 625 |
| Previous Month | 605 |
| Variance | +20 |

**Paramax Systems Corporation**

Figure 7-1

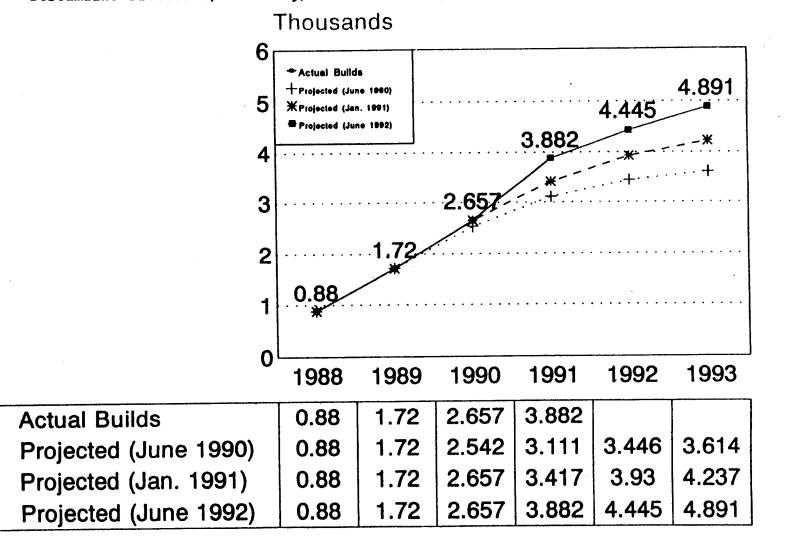## 10.   Organizational Results

Our Team Excellence program promotes continual evaluation and enhancement of our software engineering processes.   The effectiveness of this program is indicated by the major accomplishments achieved by Paramax since 1989; some of which are listed below.

- Software engineering productivity has been increased 41 percent, a savings equivalent to 140 full-time employees.

- More than 3900 modifications of the software baseline have been implemented.

- More that 850 modifications of the software baseline have been initiated.

- More than 5 million additional source lines of code have been absorbed into the baseline.

- The discrepancy report backlog has been reduced 51 percent.

- The discrepancy report density has been reduced to a record low of 69 per million lines of code.
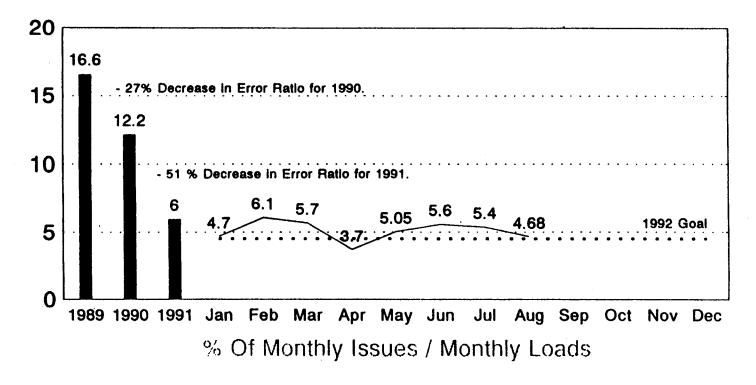
Metrics have been a powerful force in enabling us to properly plan tasks and allocate resources. Our Simulations Applications Load Build team planning activities provide an example (figure 8). The team's mission is to accept software from over 100 different sources and "bind" the software into an executable "load". In 1988 the team was producing 880 loads in a year with a projected increase in workload as depicted in the lower dotted line in figure 8. As process improvement investments began to mature, we were able to absorb an increasing work load and in each succeeding year we have reestablished our goals. We now project that the load build group will be able to produce 4891 loads in 1993 - with the same staffing level as in 1988 ! The load build group has been able to achieve these productivity levels by significantly improving the quality of their processes (figure 9). Figure 9 illustrates the effect of measuring, monitoring and goal setting. The team experienced a 16% error rate in 1989, and established a goal to reduced the rate by 25% in 1990. The team exceeded the goal and developed new goals in each subsequent year. The error rate for a very complex process is now less than five percent. Each department in Paramax has had similar success. These accomplishments have enabled us to meet the constantly increasing volume of Space Shuttle software work while operating within budget and meeting more than 98 percent of our schedule commitments.

# ACTUAL & PROJECTED RATE OF LOAD BUILD INCREASE

*Goal: Increase Productivity Without an Increase in Personnel (Automate Procedures, Streamline Processes, Training, Front End Diagnonstics).*

Thousands



| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|
| Actual Builds | 0.88 | 1.72 | 2.657 | 3.882 | | |
| Projected (June 1990) | 0.88 | 1.72 | 2.542 | 3.111 | 3.446 | 3.614 |
| Projected (Jan. 1991) | 0.88 | 1.72 | 2.657 | 3.417 | 3.93 | 4.237 |
| Projected (June 1992) | 0.88 | 1.72 | 2.657 | 3.882 | 4.445 | 4.891 |

# LOAD BUILD

## Issue Ratio
## Supporting Primary Board



**16.6**

- 27% Decrease In Error Ratio for 1990.

**12.2**

- 51 % Decrease In Error Ratio for 1991.

20 — 15 — 10 — 5 — 0

| 1989 | 1990 | 1991 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |

6    4.7    6.1    5.7    3.7    5.05    5.6    5.4    4.68    1992 Goal

% Of Monthly Issues / Monthly Loads

Track 'Issue' Per Load
Trend Progress Or Success
Establish New Goals As Old Ones Are Met

17

Figure 9

## 11. Business Results

Our TQM efforts have resulted in our becoming the software supplier of choice for NASA at the Johnson Space Center. We have steadily increased our share of the JSC software engineering market by enhancing our current contracts with momentum business, and have won six of the last seven contract competitions in which we were a bidder. We believe there is a direct correlation between our quality progress and our business success.
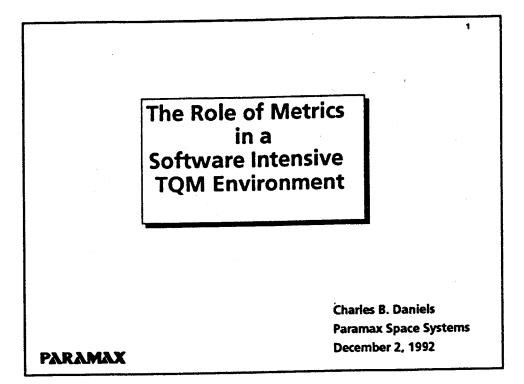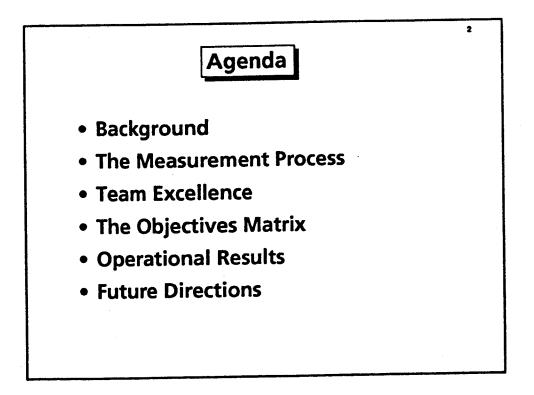
## 12. Quality Results

Paramax has received recognition from our customers, NASA and external organizations for our TQM approach, deployment and organizational results. Some of the major awards and honors we have received are the following.

- Organizational Excellence Award, the top national honor of the Association for Quality and Participation (1990)

- Johnson Space Center Team Excellence Award (1992, 1991, 1990)

- NASA Excellence Award finalist (1990, 1991, 1992)

## 13. Summary

Paramax performs one of the most complex technical tasks in our industry. Our success in this regard is directly attributable to our effective implementation of a comprehensive Total Quality Management program that places the highest priority on preventing errors. Our extensive metrics and measurements process has been the cornerstone of our quality process and has allowed us to set clearly defined, quantifiable goals; monitor our progress toward achievement; and make data-driven decisions.

# The Role of Metrics in a Software Intensive TQM Environment

Charles B. Daniels
Paramax Space Systems
December 2, 1992

**PARAMAX**

# Agenda

- Background
- The Measurement Process
- Team Excellence
- The Objectives Matrix
- Operational Results
- Future Directions

## Paramax Space Systems Software Engineering Role

- **Software products, services and support**
  - Space Shuttle/Space Station Operations
  - Mission Control Center Upgrades
  - Space Station Control Center Development
  - Software product & quality assurance at JSC
  - Space Shuttle preflight evaluation

## Initial Environment

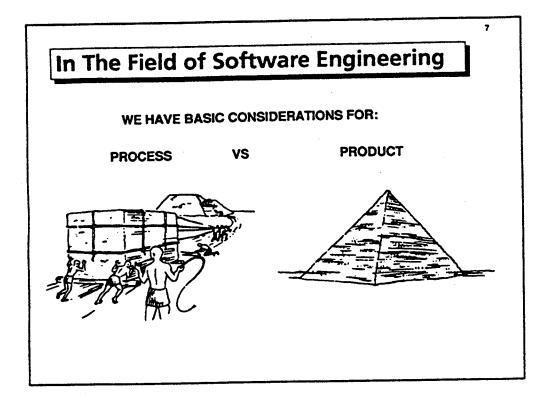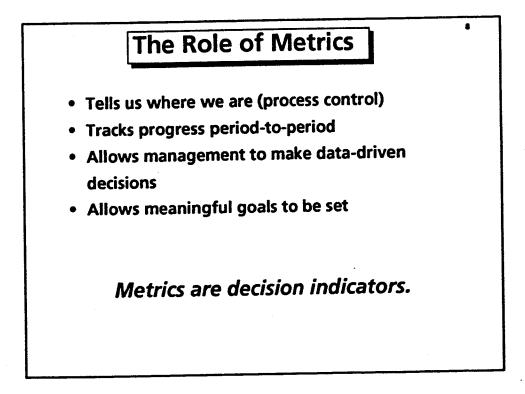| ATTRIBUTES | STSOC Facilities | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | MCC | SMS | FDCF | SPF | FTPF/ SAIL | FOT |
| **Work Content** | | | | | | |
| Software Complexity | Very | Very | Med | Med | Very | Med |
| Constraints (Schedule, Performance, etc.) | Many | Many | Some | Some | Many | Some |
| Variety of Environments | Many | Many | Many | Few | Many | Few |
| Testing Rigor/Difficulty | High | High | Med | Med | High | High |
| Software Maturity | High | Med | Med | Low | High | Low |
| Documentation Adequacy | Exc | Fair | Good | Exc | Exc | Exc |
| **Work Conditions** | | | | | | |
| Quality of Task Management | Exc | Fair | Fair | Exc | Good | Fair |
| Work Environment | High | Low | Med | High | Low | Med |
| Personnel Skill Level | Exc | Good | Good | Exc | Good | Good |
| Standards Availability/Enforcement | Exc | Fair | Fair | Exc | Good | Fair |
| Quality of Products | Exc | Fair | Good | Exc | Good | Good |
| Tools | Good | Poor | Poor | Good | Good | Poor |
| **Summary Assessment** | | | | | | |
| Job Difficulty | Med | Very High | High | High | Med | High |
| **Proposal Estimate** | | | | | | |
| (KLOC/Engineer) | 50/40 | 30 | 35 | 35 | 40 | 35 |

## Multi-process Test Bed Environment

- **Mature software evolution**
  - **Mission Control Center**
  - **Shuttle Mission Simulator**
- **New Capability Development**
  - **FADS**
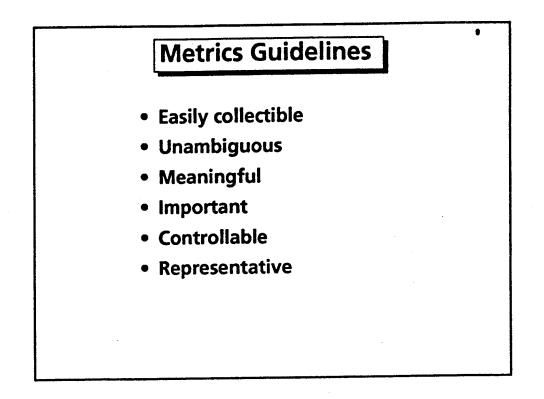- **New Methodology Development**
  - **Information Systems**

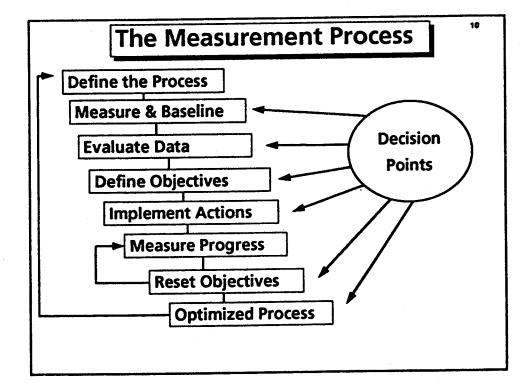## Software Engineering Management Focus

- Achieve increasing levels of:
  - Reliability
  - Productivity
  - Responsiveness
- Accomplished through:
  - Baselining existing processes
  - Developing action plans
  - Measurement and analysis
  - Teamwork

# In The Field of Software Engineering

**WE HAVE BASIC CONSIDERATIONS FOR:**

**PROCESS**      **VS**      **PRODUCT**



# The Role of Metrics

- Tells us where we are (process control)
- Tracks progress period-to-period
- Allows management to make data-driven decisions
- Allows meaningful goals to be set

*Metrics are decision indicators.*

# Metrics Guidelines

- Easily collectible
- Unambiguous
- Meaningful
- Important
- Controllable
- Representative

# The Measurement Process

Define the Process

Measure & Baseline

Evaluate Data

Define Objectives

Implement Actions

Measure Progress

Reset Objectives

Optimized Process

Decision Points

## Standard Metrics

- Organizational communications
- Common understanding
- Top-level summary
- Categories at Paramax
  - Quality Performance
  - Workflow Performance
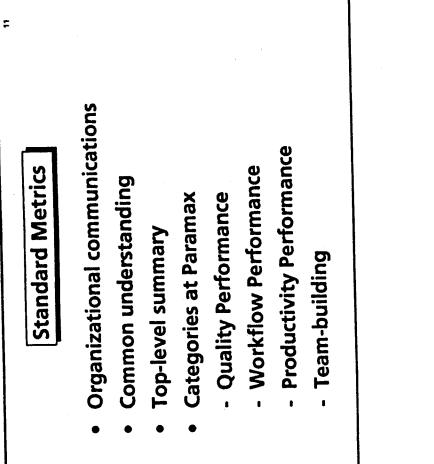  - Productivity Performance
  - Team-building

**Team Excellence Inputs**
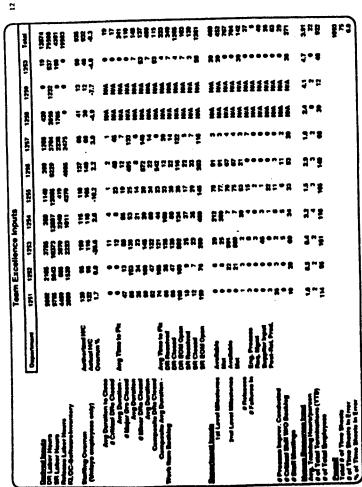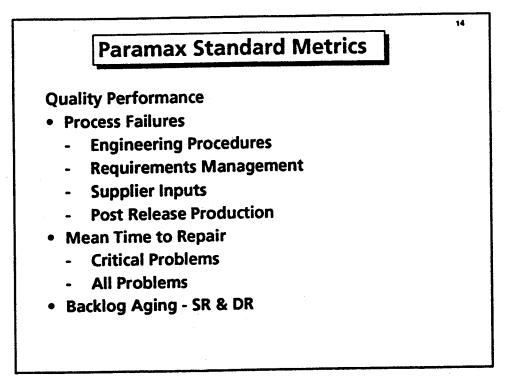
## Paramax Standard Metrics

**Workflow Performance**
- SR (Change traffic) Closure Index
- DR (Discrepancy traffic) Closure Index
- First and Second Level Milestone
- SR & DR Backlog Management

**Productivity Performance**
- Effort Expended for SRs, DRs, and Testing
- Resource Allocation
- S/W Engineering Productivity (KLOC/Engineer)

## Paramax Standard Metrics

**Quality Performance**
- Process Failures
  - Engineering Procedures
  - Requirements Management
  - Supplier Inputs
  - Post Release Production
- Mean Time to Repair
  - Critical Problems
  - All Problems
- Backlog Aging - SR & DR

# Paramax Standard Metrics

**Team Building**

- **Training**
- **Process Improvement Initiatives**
- **Staffing Efficiency and Effectivity**
- **Critical Skills Backup**
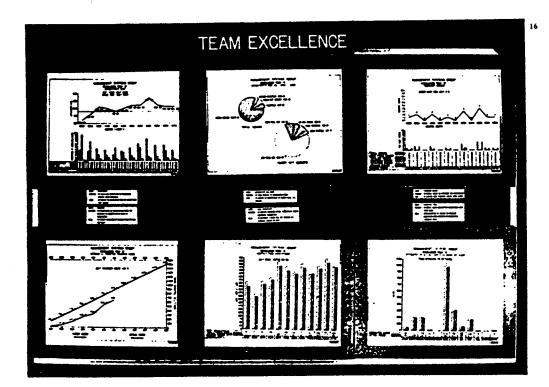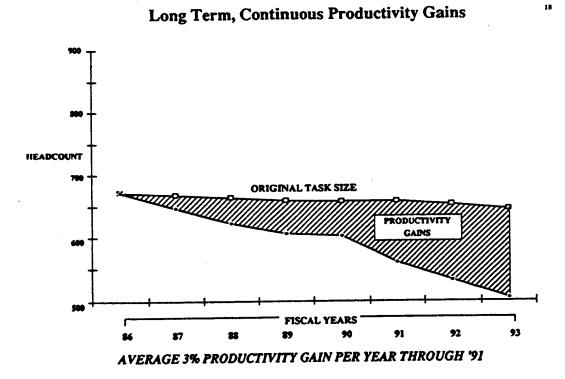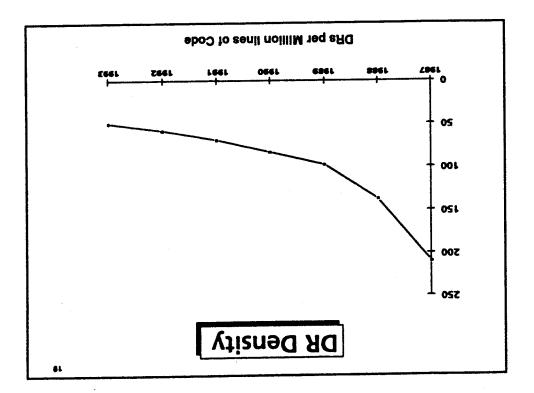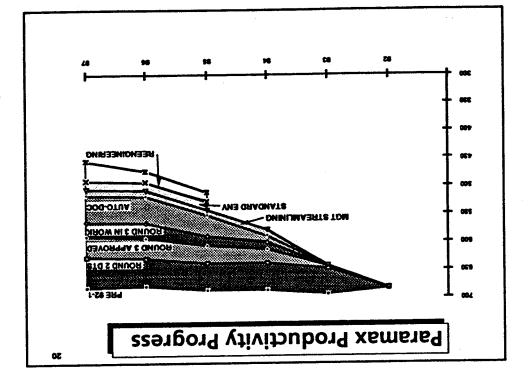- **Information Flow**
- **Skill Mix**
- **Procedure Currency**

Figure 1 - Team Excellence Primary Metrics Board

| Criteria | How Measured | This Month | OBJECTIVES MATRIX Performance Levels | | | | | | | | | | | Score | Weight | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| Criteria | How Measured | This Month | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Score | Weight | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DR Closure Index | Closure/Receipt Ratio | 1.06 | .85 | .90 | .95• | 1.00 | (1.05) | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 | 1.35 | 4 | 20 | 80 |
| SR Closure Index | Closure/Receipt Ratio | 1.30 | .80 | .85 | .90 | .95 | 1.00 | 1.05 | 1.10 | 1.15 | 1.20• | 1.25 | (1.30) | 10 | 20 | 200 |
| Milestones Met | No. 1st Level Milestones Met (%) | 97.9 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | (97) | 98• | 99 | 100 | 7 | 15 | 105 |
| SR Backlog | EOM Open SRs | 900 | 1500 | 1400 | 1300 | 1200 | 1100 | 100• | (900) | 800 | 700 | 600 | 500 | 6 | 15 | 90 |
| DR Backlog | EOM Open DRs | 960 | 1500 | 1400 | 1300• | 1200 | 1100 | (1000) | 900 | 800 | 700 | 600 | 500 | 5 | 10 | 50 |
| Critical DR Responsiveness | Mean Time to Fix Critical DRs | 14 | 25 | 23 | 21 | 19 | 17 | (15) | 13 | 11• | 9 | 7 | 5 | 6 | 10 | 60 |
| Critical DR Age | Average Age of EOM Open Critical DRs | 8 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | (24)• | 10 | 10 | 100 |

Circle Current Month's Score ○
Solid dot for Prior Month's Score ●

| | |
|---|---|
| Current Month | 625 |
| Previous Month | 605 |
| Variance | +20 |

**Paramax Systems Corporation**

# Long Term, Continuous Productivity Gains



AVERAGE 3% PRODUCTIVITY GAIN PER YEAR THROUGH '91

# Our Challenge

- Develop a better understanding of processes associated with the "product" aspect of software engineering.

- Develop metrics to measure the performance of "product" processes.

- An ultimate goal of improving the entire software engineering lifecycle.