

PSM PRESENTATION

Engineering Process and Tools Organization (EP&TO)

**Deploying Cost-Effective Software Quality Metrics Using
Dynamic Process Modeling: A Methodology & Case History**

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Keystone, Colorado

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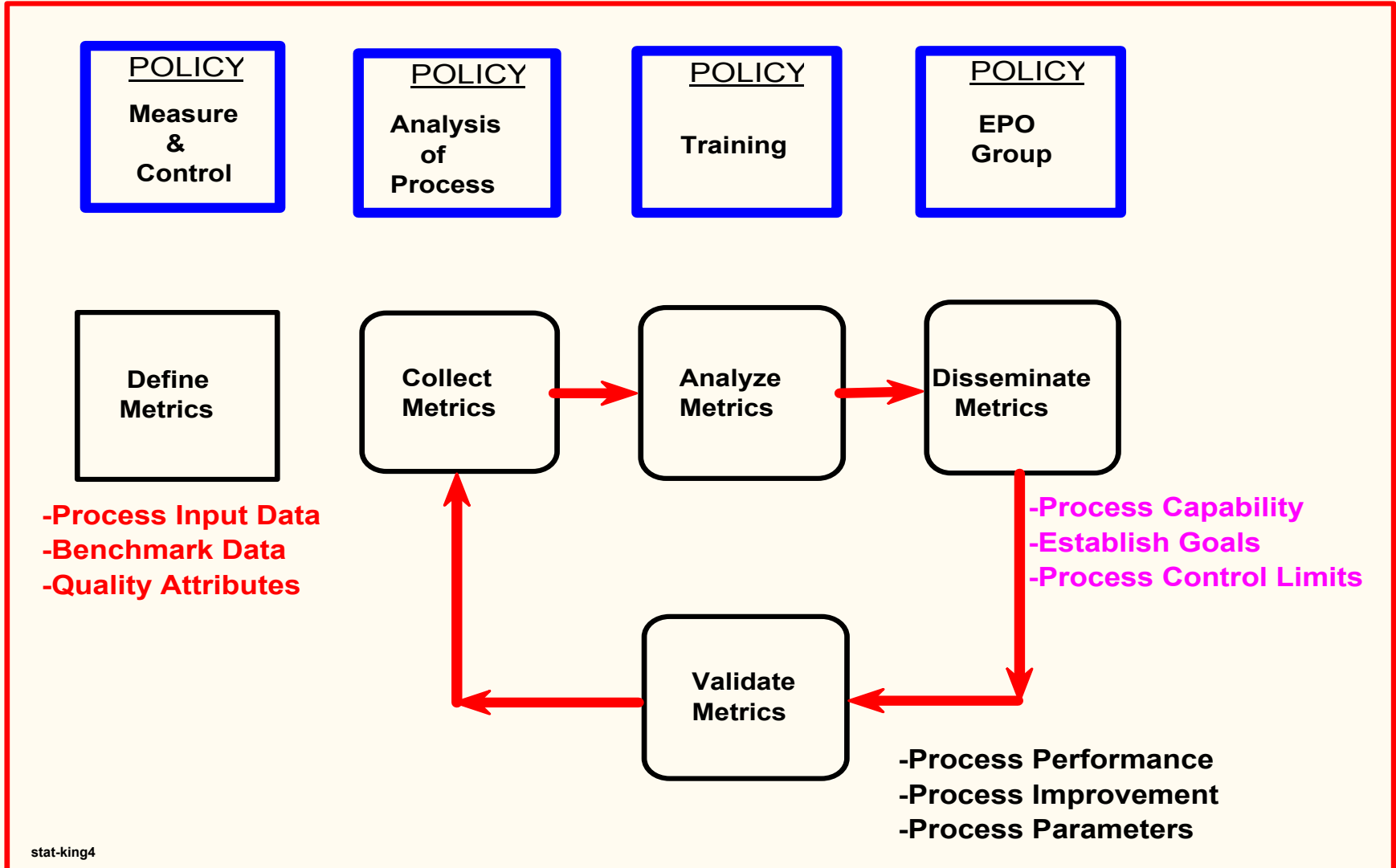
Process Modeling

DEPLOYING COST EFFECTIVE SOFTWARE QUALITY METRICS USING DYNAMIC PROCESS MODELING: A METHODOLOGY & CASE HISTORY

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Process Modeling



Process Modeling

SOFTWARE METRICS

I. PROGRAMMATIC METRICS

1. SOFTWARE COST
2. SOFTWARE SCHEDULE
3. SOFTWARE EFFORT (PERSON-MONTHS)
4. SOFTWARE SIZE (EXECUTABLE LINES OF COD)
5. SOFTWARE COMPLEXITY
6. SOFTWARE RISK (ECONOMIC & TECHNOLOGY)
7. STAFF (HEADCOUNT)

II. PERFORMANCE METRICS

1. SOFTWARE DEFECTS (SEVERITY LEVELS)
2. SOFTWARE DEFECT DENSITY (DEFECTS PER 1,000 SLC)
3. SOFTWARE PRODUCTIVITY (SLOC / STAFF-MONTH)
4. SOFTWARE CPU & MEMORY
5. SOFTWARE SLOC GROWTH RATE
6. SOFTWARE STABILITY & VOLATILITY
7. SOFTWARE OPERATIONAL AVAILABILITY

Process Modeling

SOFTWARE METRICS

III. QUALITY METRICS

1. SOFTWARE RELIABILITY
2. SOFTWARE MAINTAINABILITY
3. SOFTWARE DEPENDABILITY
4. SOFTWARE INTER-OPERABILITY
5. SOFTWARE SURVIVABILITY
6. SOFTWARE EXPANDABILITY
7. SOFTWARE PORTABILITY

IV. COMPUTER SCIENCE METRICS

1. NUMBER OF COMMON & UNIQUE OPERATORS
2. NUMBER OF COMMON & UNIQUE OPERANDS
3. SOFTWARE CYCLOMATIC COMPLEXITY
4. SOFTWARE VOLUME
5. SOFTWARE EFFICIENCY
6. OOA / OOD--DEPTH OF INHERITANCE TREE
7. OOA / OOD--LACK OF COHESION

Process Modeling

"SEVEN (7) GOLDEN" METRICS

- I. COST PERFORMANCE INDEX (CPI)
- II. SCHEDULE PERFORMANCE INDEX (SPI)
- III. DEFECTS (DEFECT DENSITY & CONTAINMENT)
- IV. SOFTWARE PRODUCTIVITY
- V. LEARNING
- VI. RETENTION
- VII. DIVERSITY

Process Modeling

CPI & SPI METRICS

INPUT PARAMETERS:

- A) BCWS: BUDGETED COST OF WORK SCHEDULE
- B) BCWP: BUDGETED COST OF WORK PERFORMED
- C) ACWP: ACTUAL COST OF WORK PERFORMED

CALCULATED VALUES:

SCHEDULE PERFORMANCE INDEX: SPI = BCWP / BCWS

COST PERFORMANCE INDEX: CPI = BCWP / ACWP

SCHEDULE VARIANCE: SV = (BCWP) - (BCWS)

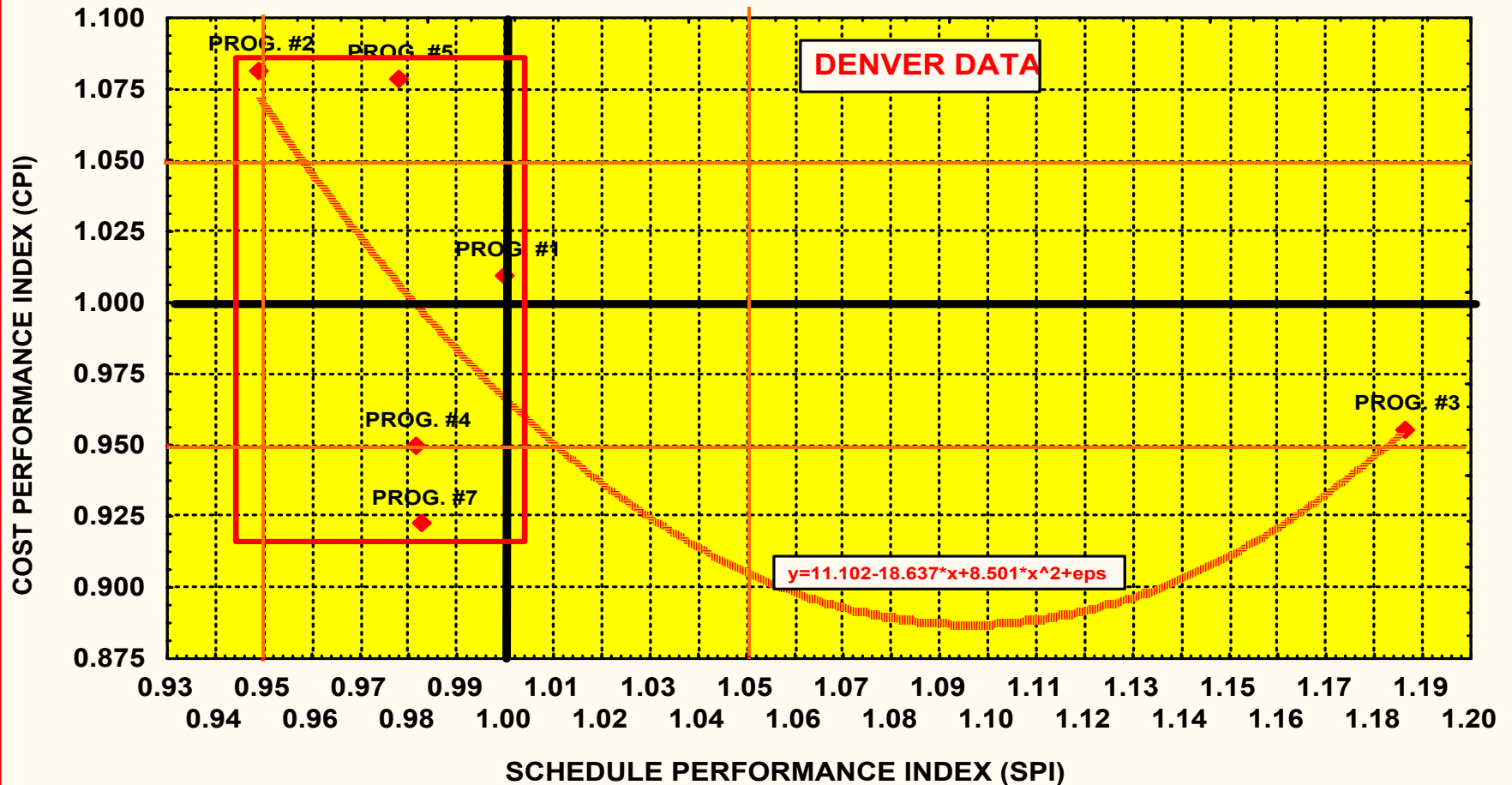
COST VARIANCE: CV = (BCWP) - (ACWP)

PERCENT SCHEDULE VARIANCE: PCTSV = ((BCWP - BCWS) / BCWS) * 100.

PERCENT COST VARIANCE: PCTCV = ((BCWP - ACWP) / BCWP) * 100.

Process Modeling

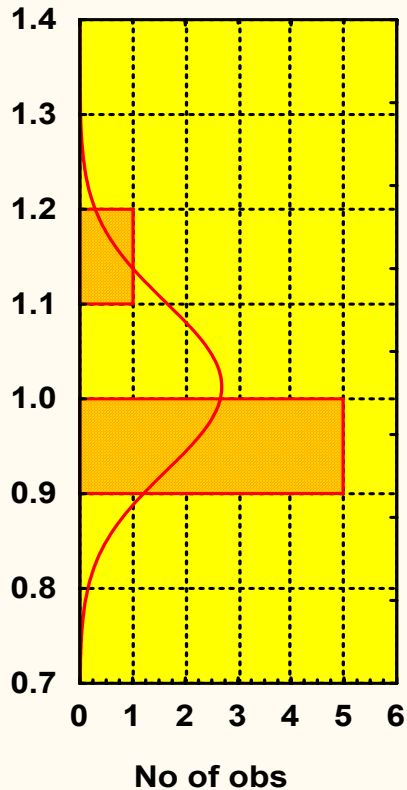
DR. AARON N. SILVER--PROCESS MODELING--DATA (AUG2000.STA)
REGRESSION ANALYSIS--FILE#:REGAUG00.STG--OCTOBER 2, 2001



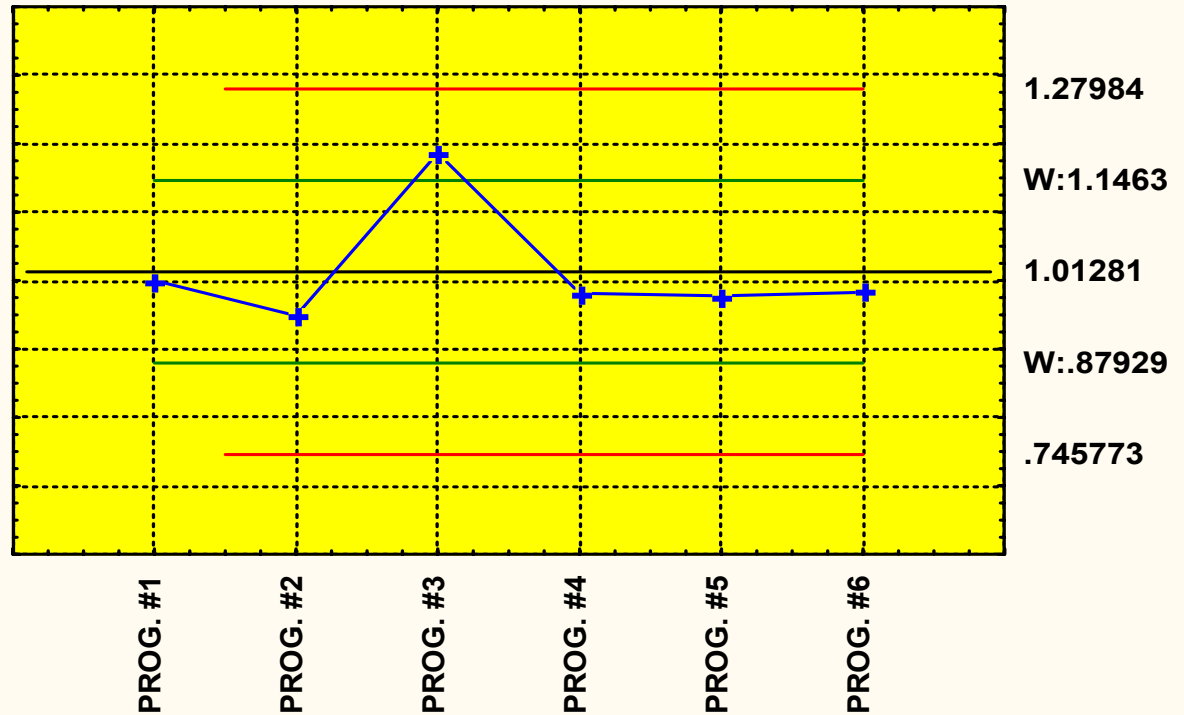
Process Modeling

X-Bar chart: SPI--SCHEDULE PERFORMANCE INDEX

Histogram of Means



DR. AARON N. SILVER--PROCESS MODELING--SPI DATA
X-BAR Mean:1.01281 (1.01281) Proc. sigma:.089011 (.089011) n:1
Specifications: LSL=.926256 Nominal=1.01281 USL=1.09936
CONTROL CHART (MEAN)--FILE#:AUG00SPI--OCTOBER 2, 2000



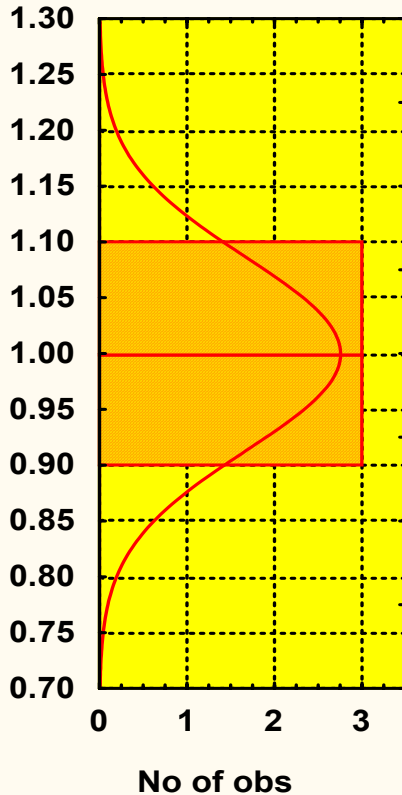
DENVER PROGRAMS--AUGUST 2000--SPI DATA (AUG. 2000)

1.27984
W:1.1463
1.01281
W:.87929
.745773

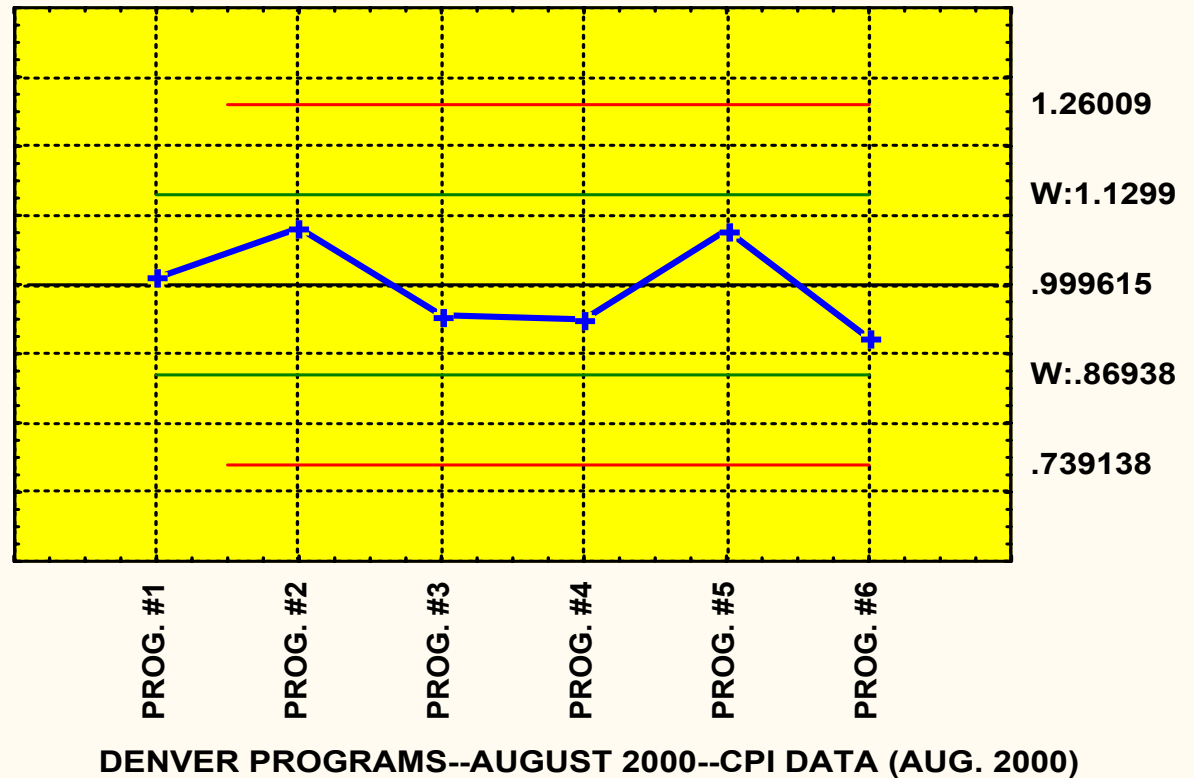
Process Modeling

X-Bar chart: CPI--COST PERFORMANCE INDEX

Histogram of Means



DR. AARON N. SILVER--PROCESS MODELING--CPI DATA
 X-BAR Mean: .999615 (.999615) Proc. sigma: .086826 (.086826) n:1
 Specifications: LSL=.931020 Nominal=.999615 USL=1.06821
CONTROL CHART (MEAN)--FILE#:AUG00CPI--OCTOBER 2, 2000

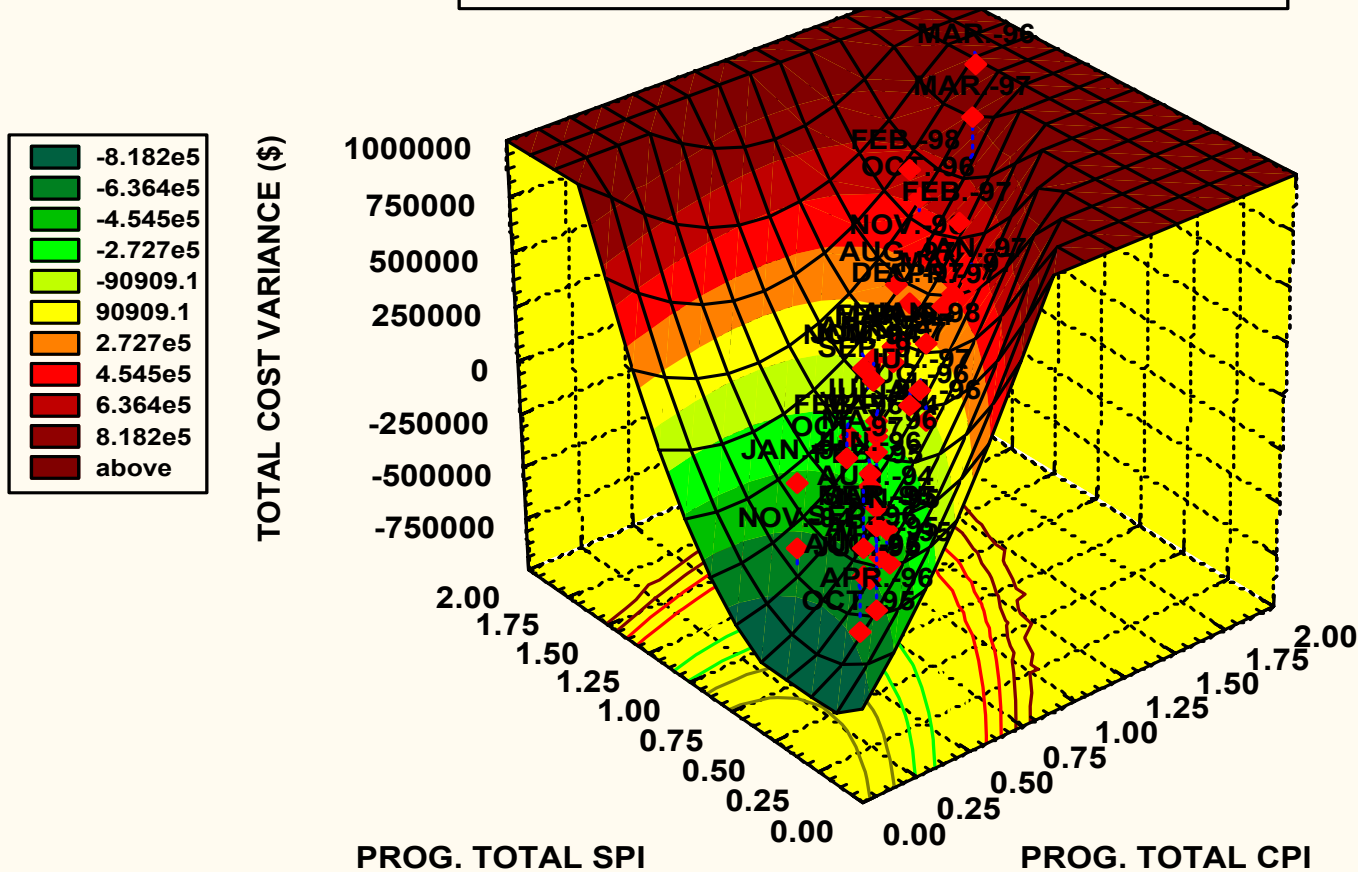


DENVER PROGRAMS--AUGUST 2000--CPI DATA (AUG. 2000)

Process Modeling

DR. AARON N. SILVER--PROCESS METRICS--PROG. DATA
 QUADRATIC PREDICTION MODEL--FILE#:DCS3D15A.STG--JUNE 9, 2001

$$z = -8.721e5 + 1.501e6 * x - 1.045e6 * y + 8.333e5 * x * x - 1.865e6 * x * y + 1.444e6 * y * y$$

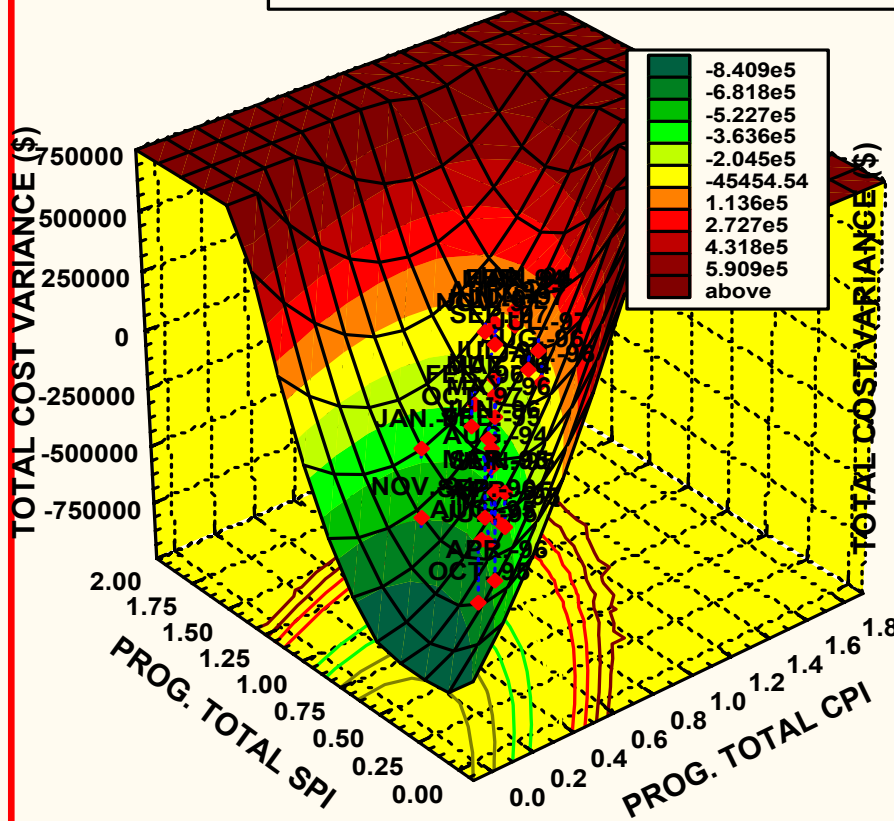


Process Modeling

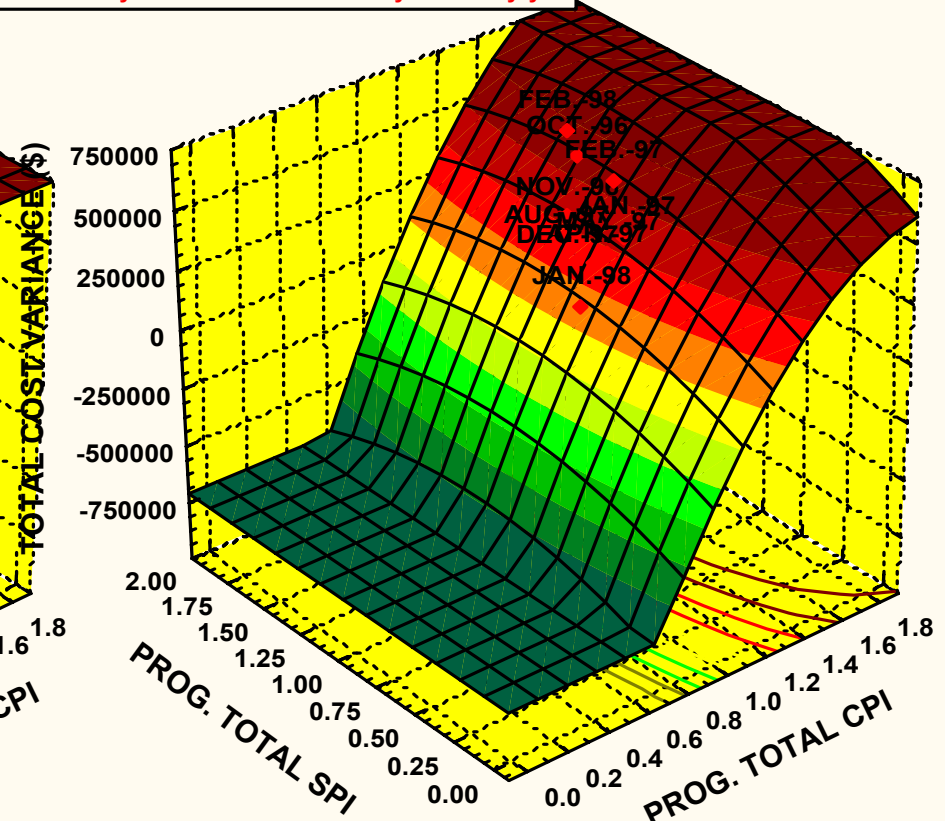
DR. AARON N. SILVER--PROCESS METRICS--PROG. DATA

QUADRATIC PREDICTION MODEL--FILE#:DCCS4D1A.STG--JUNE 9, 2001

TOTAL COST VARIANCE: ≤ 0 $z = -8.143e5 + 1.421e6*x - 1.106e6*y + 1.108e6*x*x - 2.258e6*x*y + 1.63e6*y*y$
 TOTAL COST VARIANCE: > 0 $z = -2.824e6 + 3.454e6*x + 2.845e5*y - 8.623e5*x*x + 1.079e5*x*y - 1.682e5*y*y$



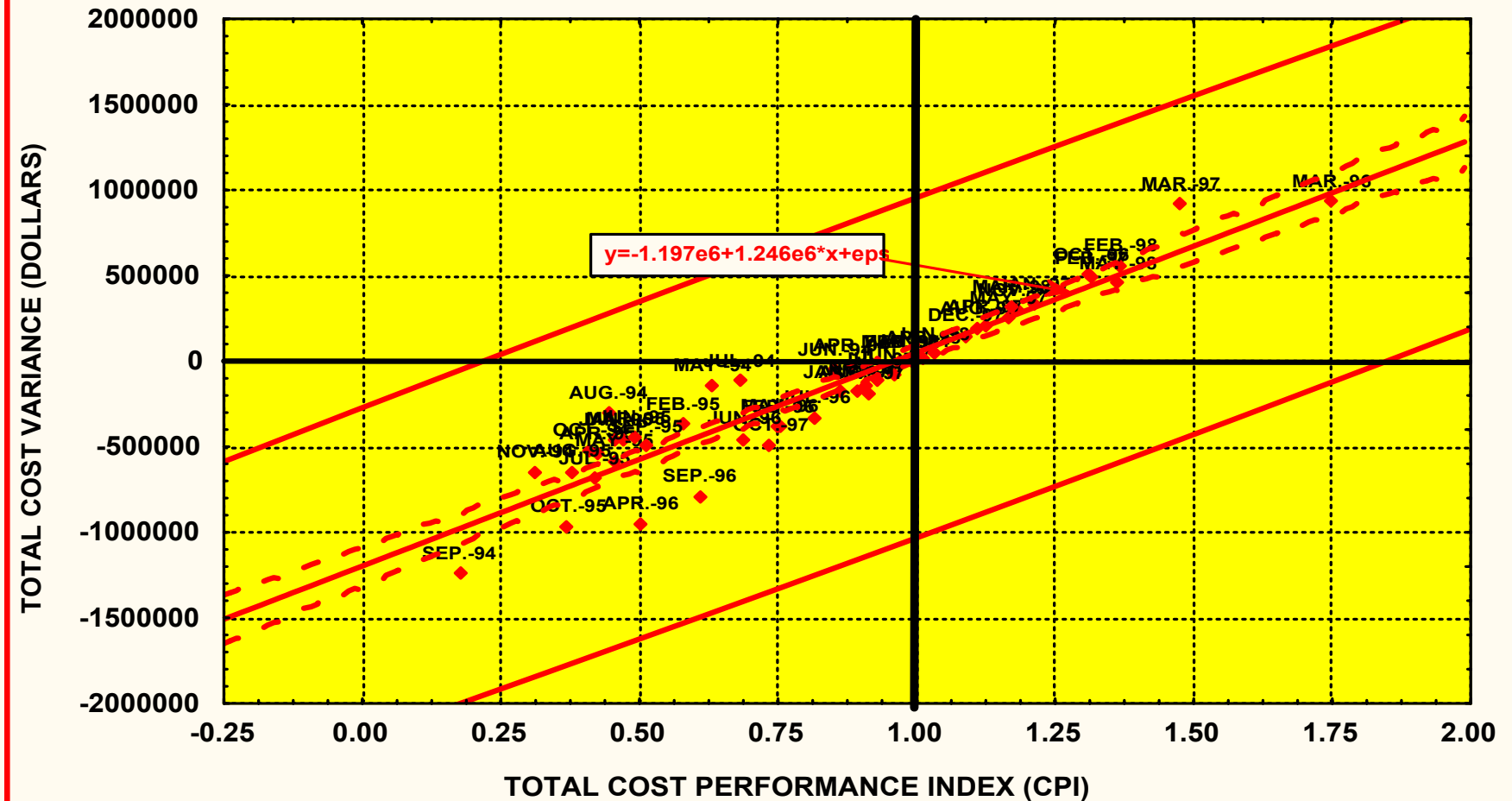
TOTAL COST VARIANCE ≤ 0 : OVER RUNS



TOTAL COST VARIANCE > 0 : UNDER RUNS

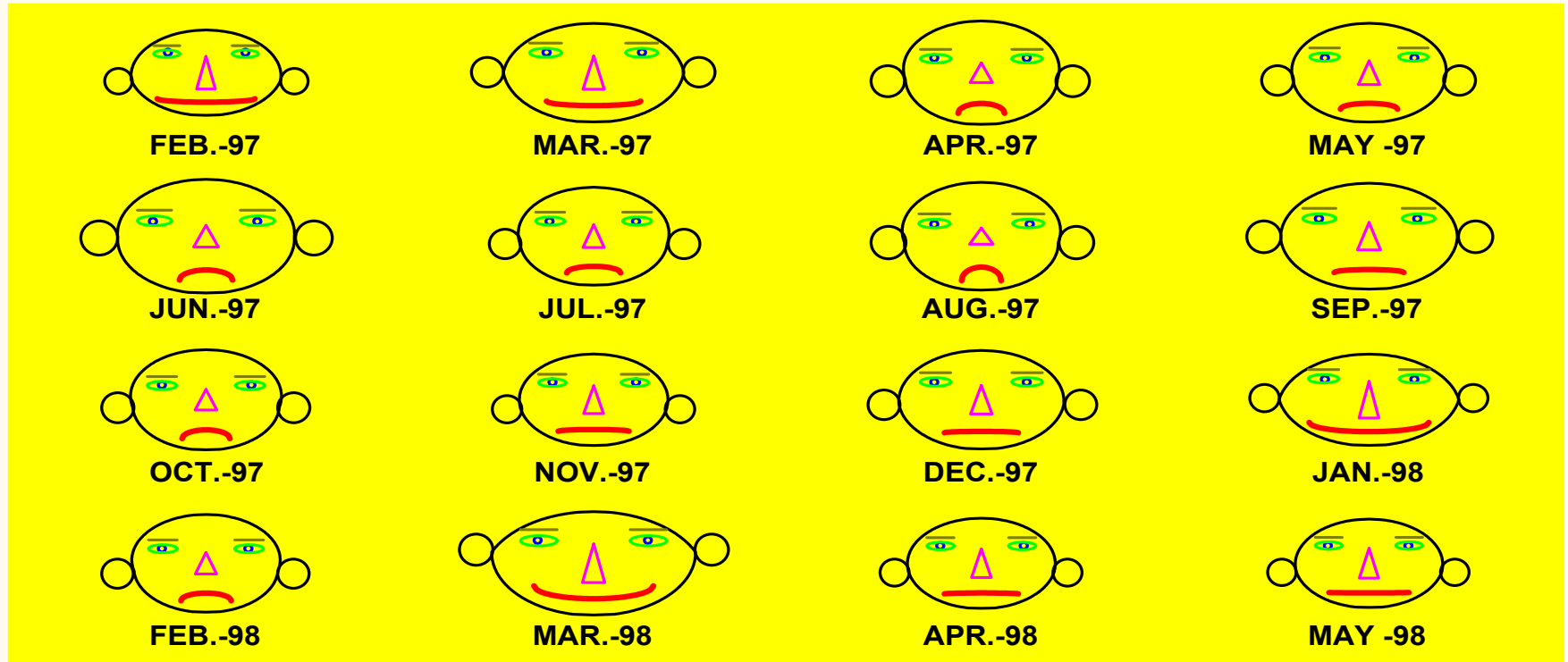
Process Modeling

DR. AARON N. SILVER--PROCESS METRICS--DATA (TOTAL)
REGRESSION ANALYSIS--FILE#:DCCSLN01.STG (DCCS1)--JUNE 22, 2001



Process Modeling

DR. AARON N. SILVER--PROCESS METRICS
 FILE#:DCCSCHR2.STG (DCCS1)--JULY 7, 2001



CHERNOFF FACES--MANAGEMENT COMPONENT (DOLLAR DERIVED)

LEGEND: face/w = MGT. BCWS, ear/lev = MGT. BCWP, halfface/h = MGT. ACWP,
 upface/ecc = MGT.SCH.VAR., loface/ecc = MGT.PCT.SCH.VAR., nose/l = MGT.PCT.COST VAR.,
 mouth/cent = MGT. SPI, mouth/curv = MGT. COST VAR., mouth/l = MGT. CPI,

Process Modeling



Balanced Scorecard

Planning

Raytheon

Command, Control, Communication and Information Systems (C³I)

Financial

Strategic Objective

- Growth Orientation & Financial Strength

Measurement

Negotiation metric
Cash Revenue - 2004
Margin
Annual growth
ROIC

Strategic Objective

- Process Improvement
- Integrated Planning & Forecasting
- FEOTB - Market, Capture, Propose
- Develop Business Solutions / Products & Services

Measurement

Defect Rate
ROI on Improvements
Productivity Improvement (O/H)

% Functional Groups in Plans
Performance to Plan

Funnel of Opportunities
Balance of Business Portfolio
Capture Rate
ROIC

Product Development Cycle Time
% License & Maintenance Fees / Sales

Process

Customer

Strategic Objective

- Meet Commitments, Expectations Easy to do Business with
- Protect, Expand, Diversify Customer Base

Measurement

Gate 5 reviews
Composite award fee
SPI
CPI

of New Acquisition Sources
Market Share

Strategic Objective

- Share Best Practices and Lessons Learned
- Focused People Strategy
- Skill Development
- Investment - People, Assets, Technology

Measurement

Build / Reuse Ratio
Gate II Completion

Strategic Job Coverage Ratio
Successors / Critical Positions
Retention Rate

Critical Skill / Need Ratio
Skill Training Plan
Performance to Plan

Targeted R&D to Sales
Actual R&D to Sales
ROIC

Learning

■ Lead
 ■ Lag

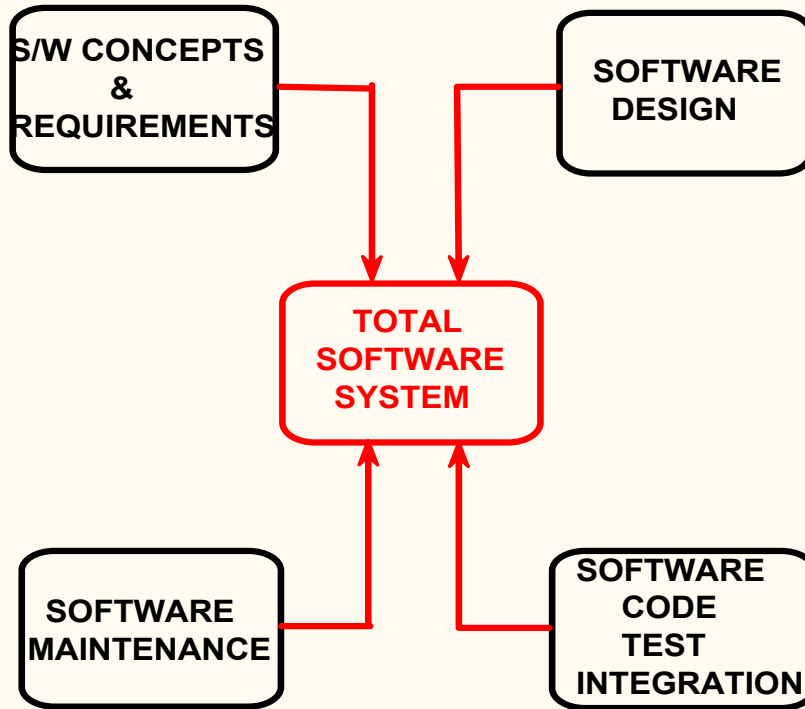


“Classic Balanced Scorecard”



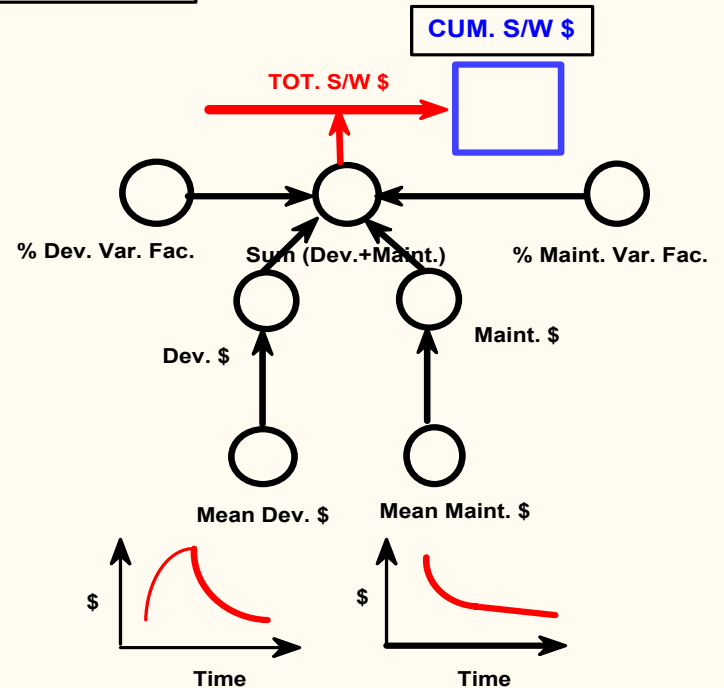
Process Modeling

SOFTWARE PROCESS MODEL



SYSTEMS MODEL

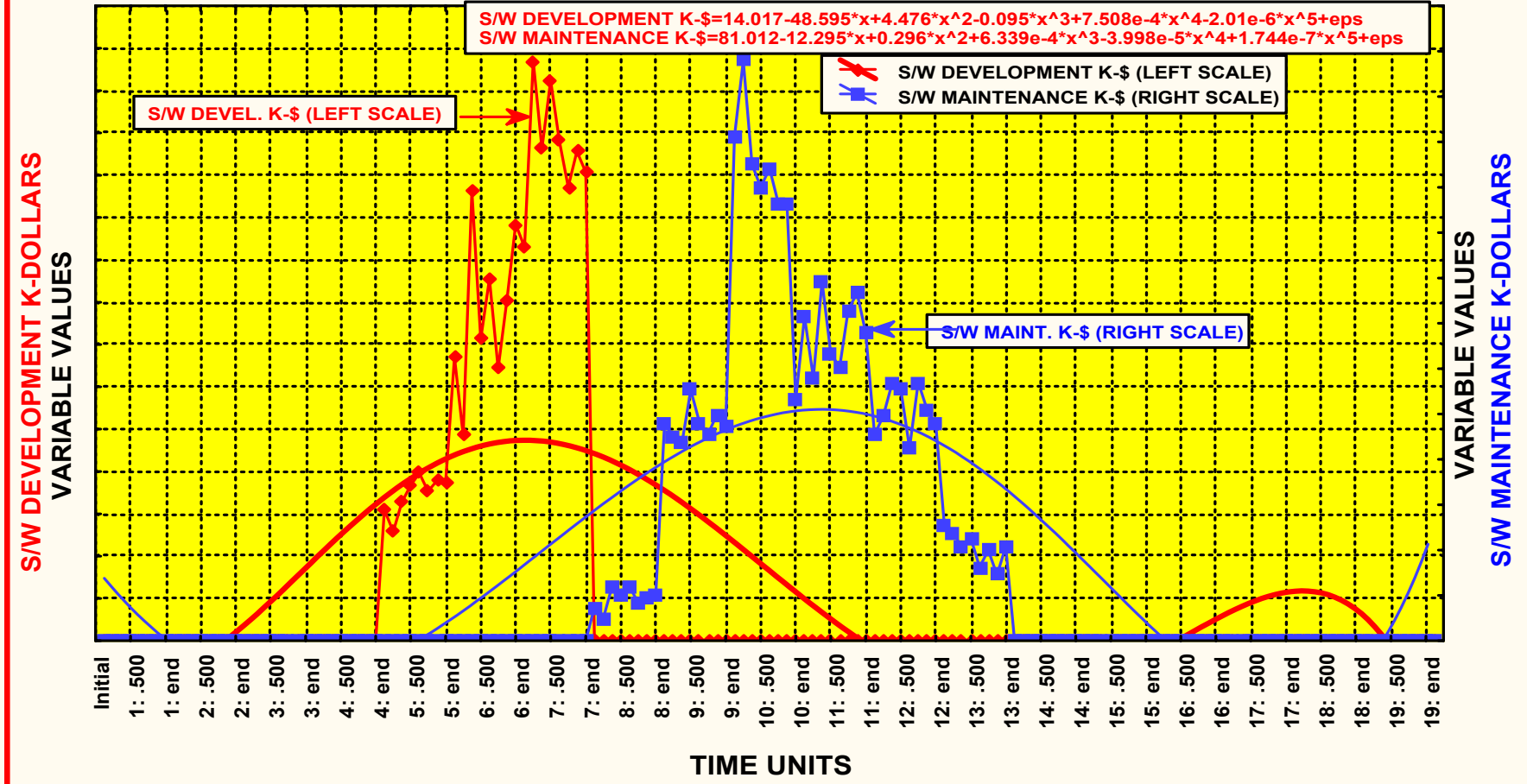
PRCMOD01.STG



EXECUTION MODEL

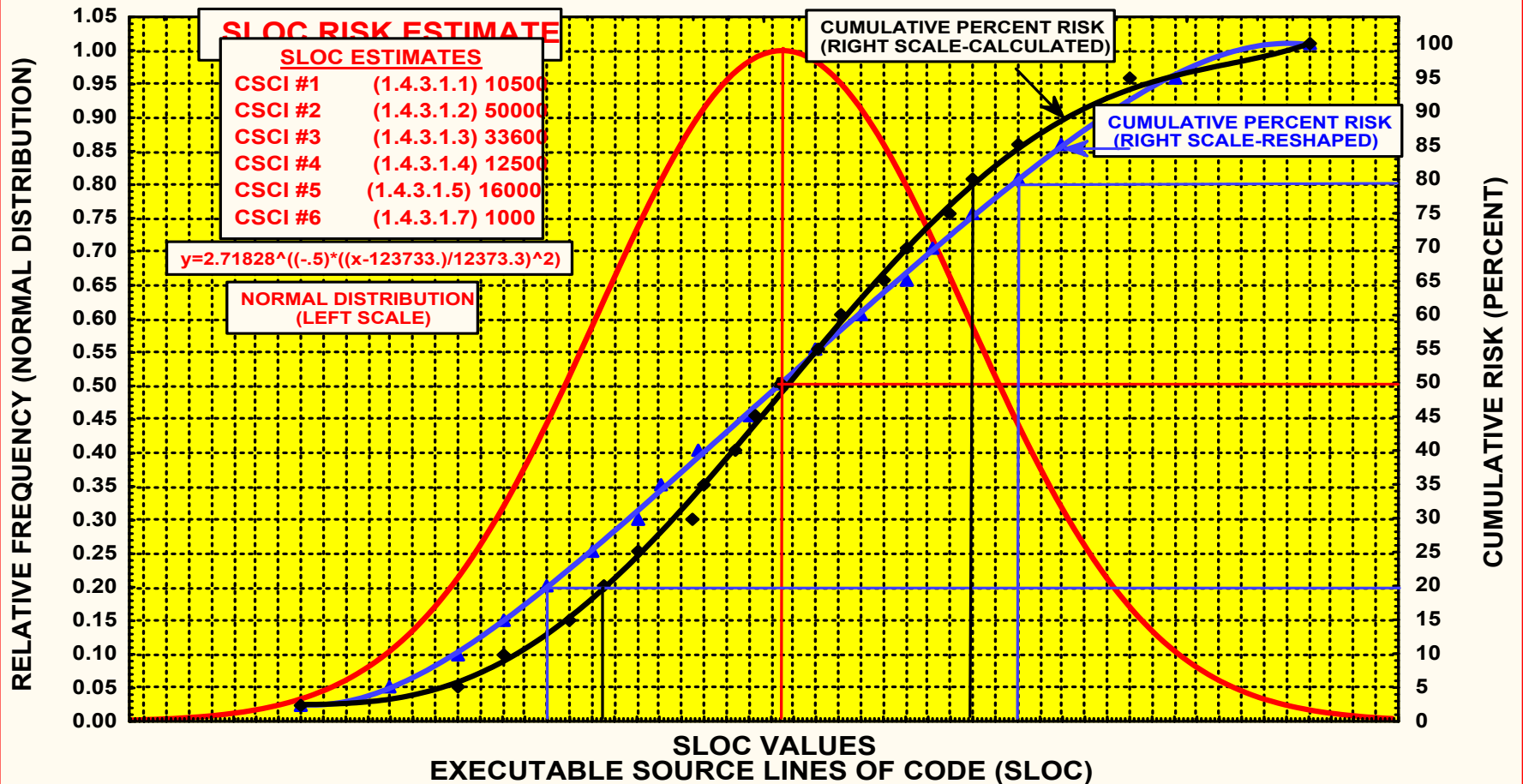
Process Modeling

DR. AARON N. SILVER--S/W MODELING--DATA (NPPTAB04.STA)
REGRESSION ANALYSIS--FILE#:NPPREG05.STG--DECEMBER 12, 2001



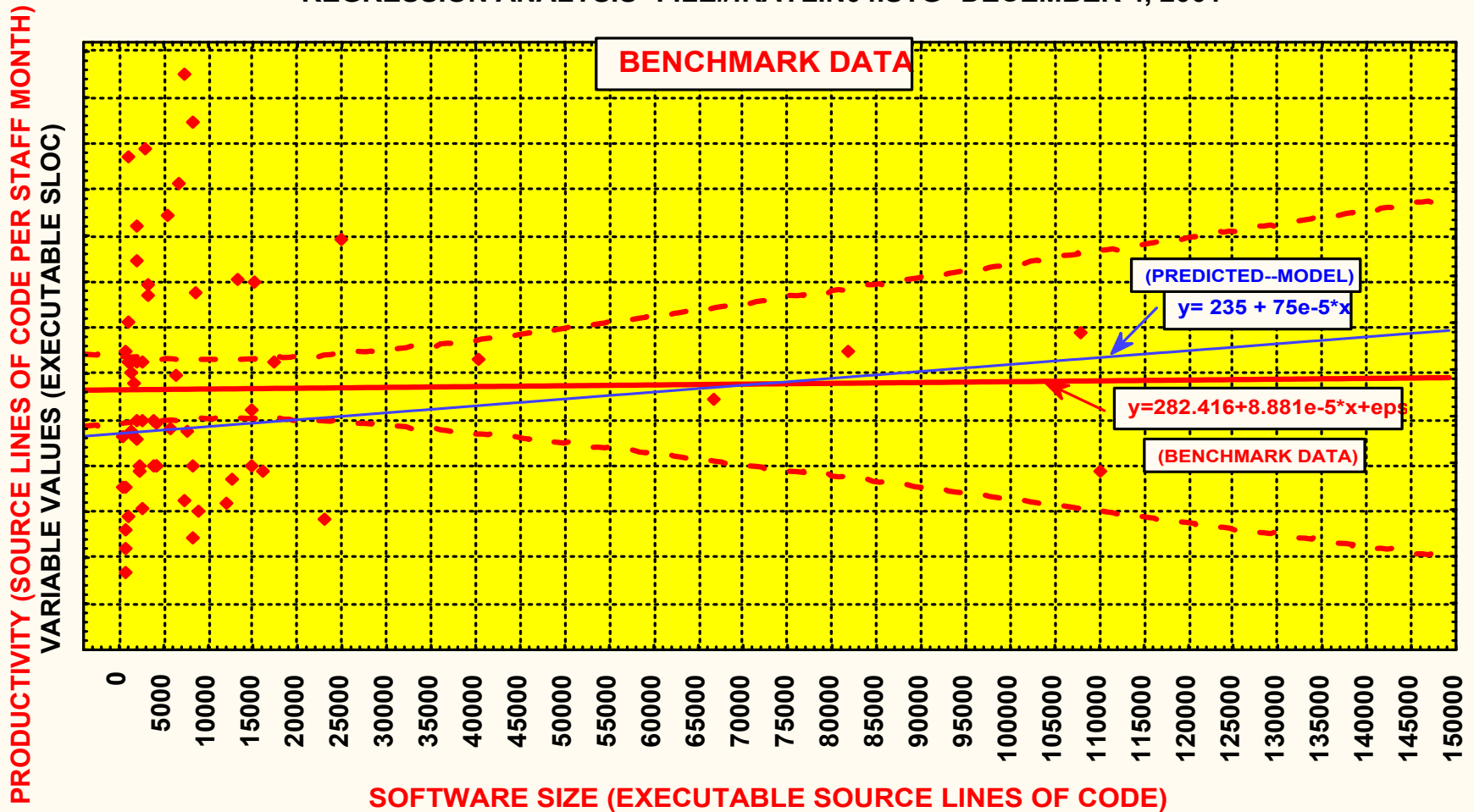
Process Modeling

DR. AARON N. SILVER--RISK PROFILE--DATA (SASRSK.STA)
RISK ANALYSIS--FILE#:NPPSLOC1.STG--DECEMBER 4, 2001



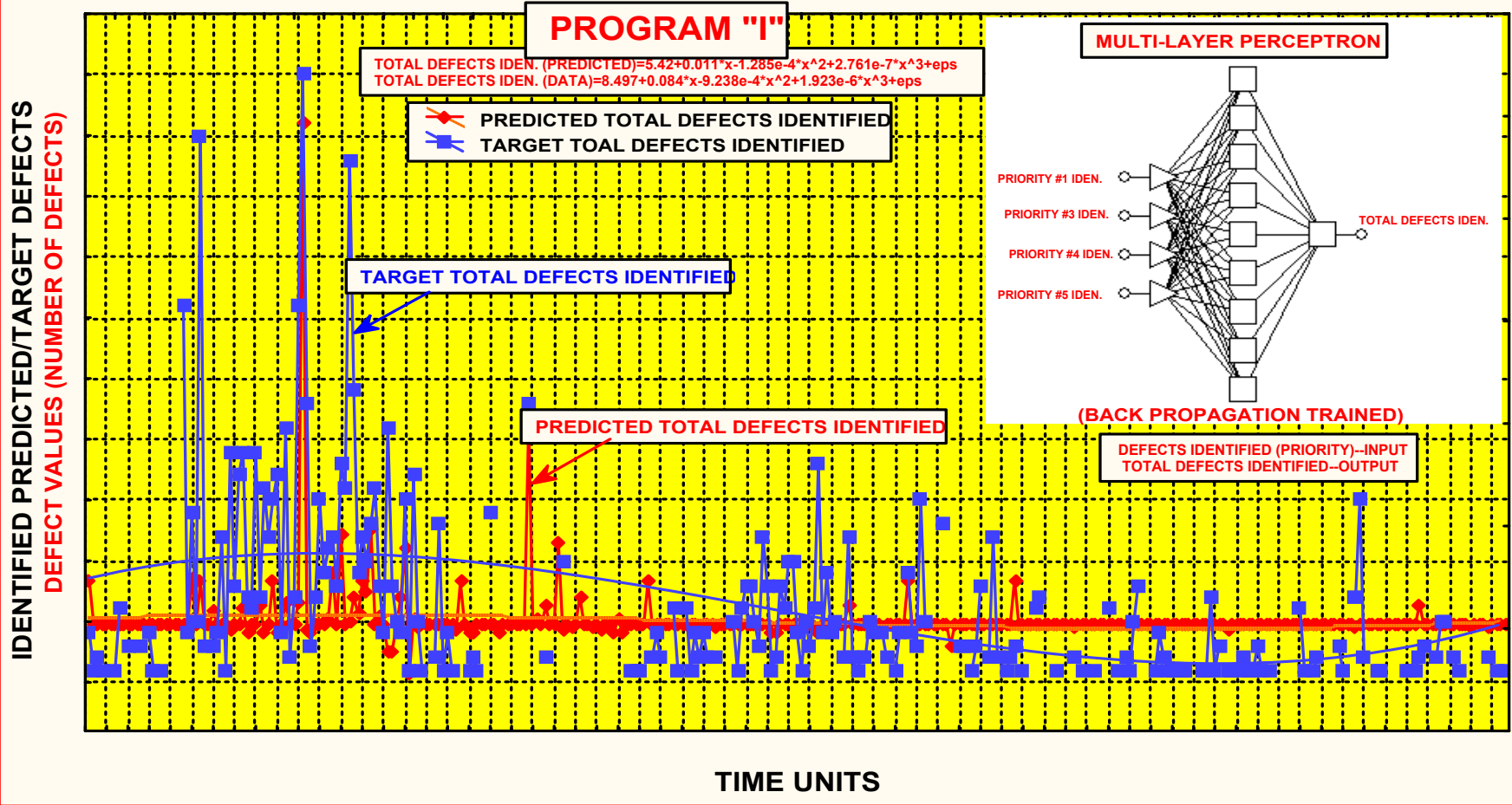
Process Modeling

DR. AARON N. SILVER--BENCHMARK METRICS (DATA:RAYPROD01.STA)
REGRESSION ANALYSIS--FILE#:RAYLIN04.STG--DECEMBER 4, 2001



Process Modeling

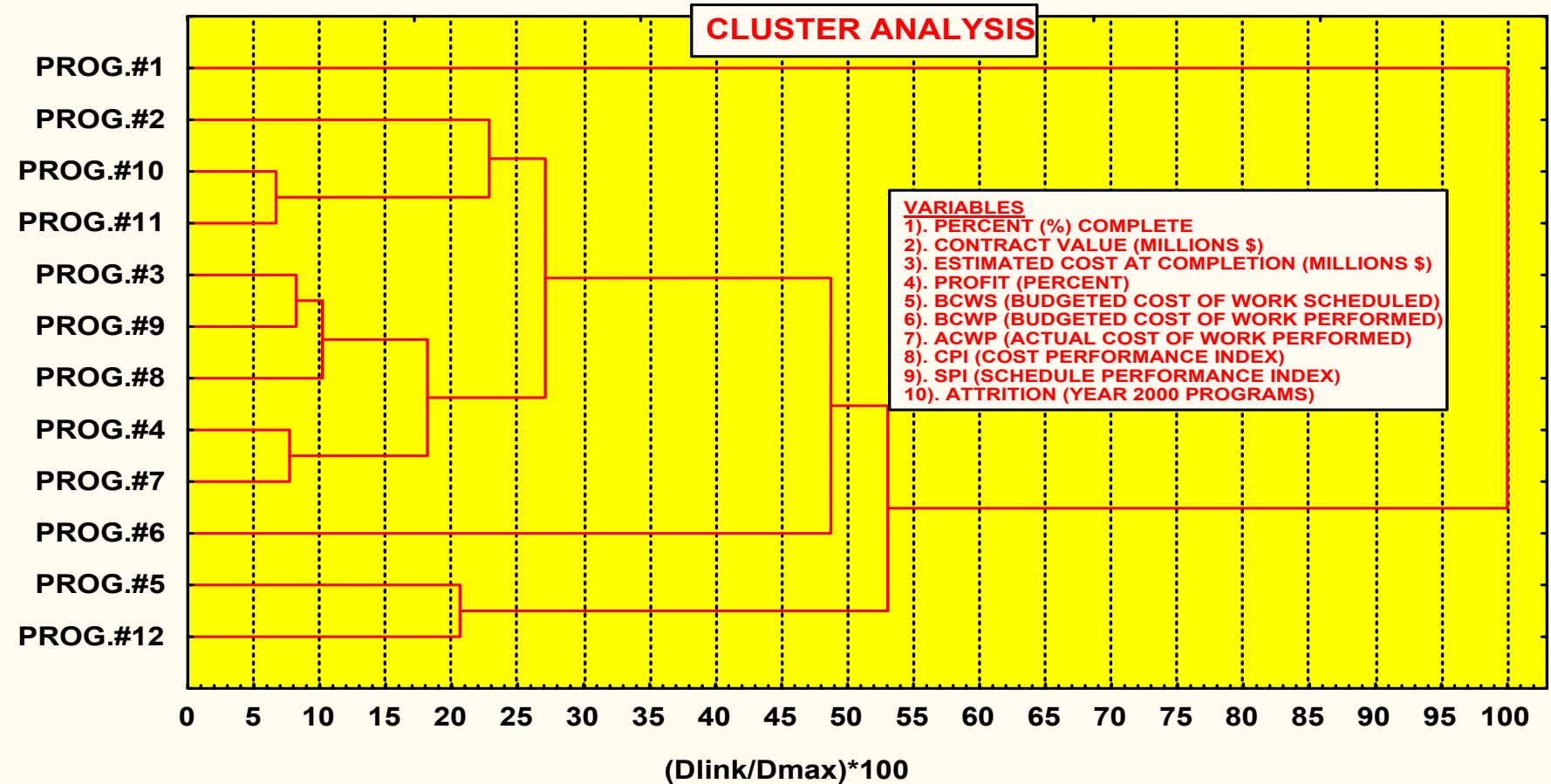
NEURAL NETWORKS--DR. AARON N. SILVER--DATA (INDIA1.STA)
REGRESSION ANALYSIS--FILE#:NETREG01.STG--AUGUST 31, 2001



Process Modeling

DR. AARON N. SILVER--PROCESS MODELING--FILE#:FWCLS04.STG

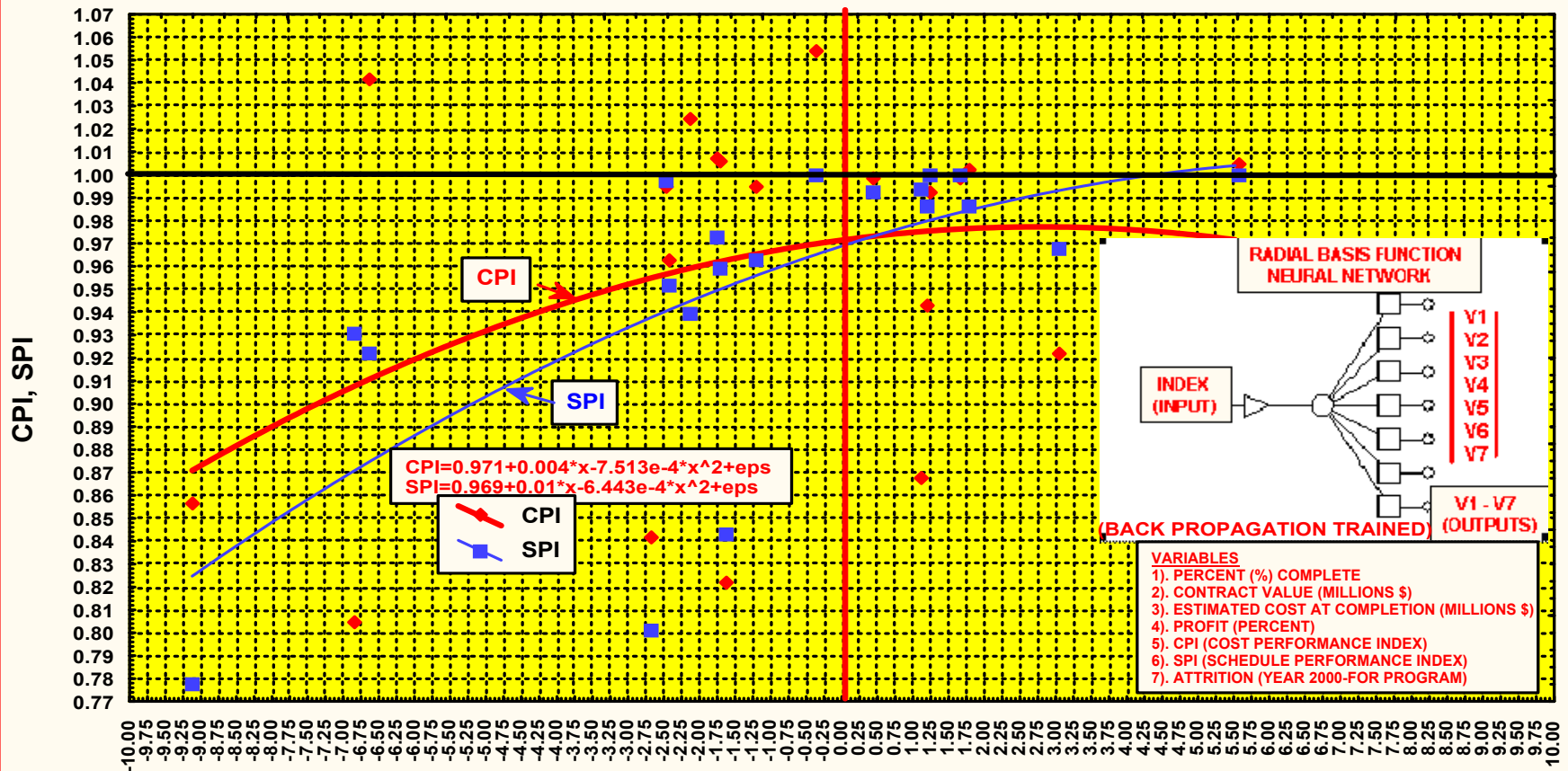
Cluster Analysis--Unweighted pair-group average (euclidean Dist.)---1/23/02



Process Modeling

DR. AARON N. SILVER--PROCESS MODELING--DATA (C3IDATA.STA)

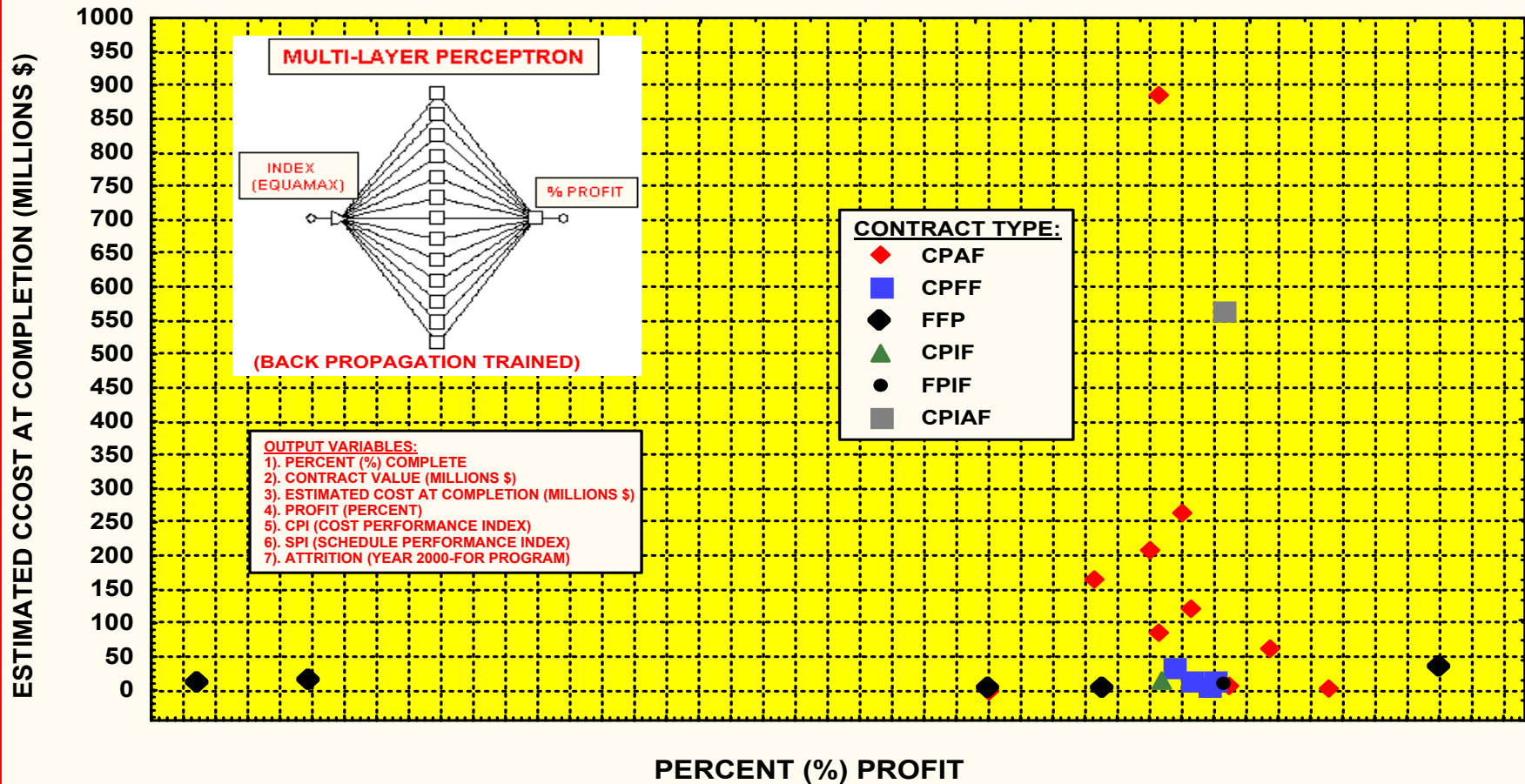
NEURAL NETWORK/REGRESSION--FILE#:INDNET4A.STG--JANUARY 26, 2002



GENERALIZED PERFORMANCE INDEX (NORMALIZED EQUAMAX ROTATION DERIVED)

Process Modeling

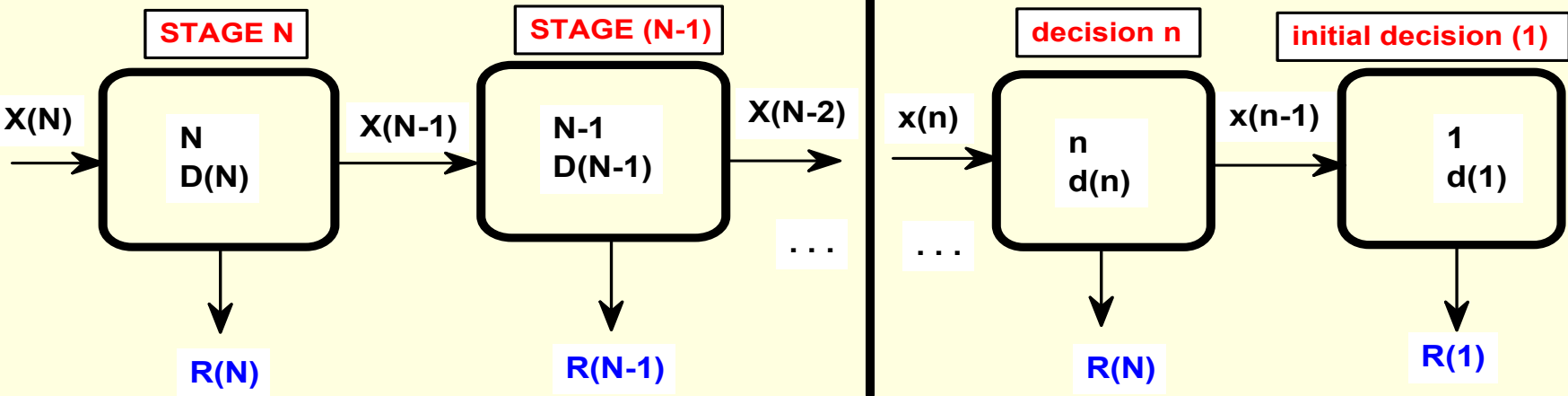
DR. AARON N. SILVER--PROCESS MODELING--DATA (C3IDATA.STA)
NEURAL NETWORK ANALYSIS--FILE#:NEUCON06.STG--JANUARY 29, 2002



Process Modeling

DR. AARON N. SILVER--FILE#:DYNPC04.STG--OCTOBER 6, 2001

$X(N)$ =STATES OF SYSTEM AT STAGE N
 $R(N)$ =RETURN FROM STAGE N
 $D(N)$ =DECISION AT STAGE N



n =specific stage "n"
 $d(n)$ =specific decision at stage "n"

BELLMAN'S PRINCIPLE OF OPTIMALITY
"An optimal set of decisions to an n stage process has the property that no matter what the state of the input of the system is at stage n , and no matter what decision is made at stage n , the remaining decisions must be optimal with respect to the state resulting from the n th stage decision."

$$Q_n(X_n, D_n) = R_n(X_n, D_n) + F_{n-1}(X_{n-1})$$

$$\text{and } F_n(X_n) = \text{Max}_{d_n} \{ Q(X_n, D_n) \}$$

DYNPC04.STG

Process Modeling

DR. AARON N. SILVER--PROCESS MODELING--DATA (SILTXT.STA)
DYNAMIC PROGRAMMING--FILE#:DYNDAT01.STG--FEBRUARY 5, 2001

REQUIREMENTS ANALYSIS

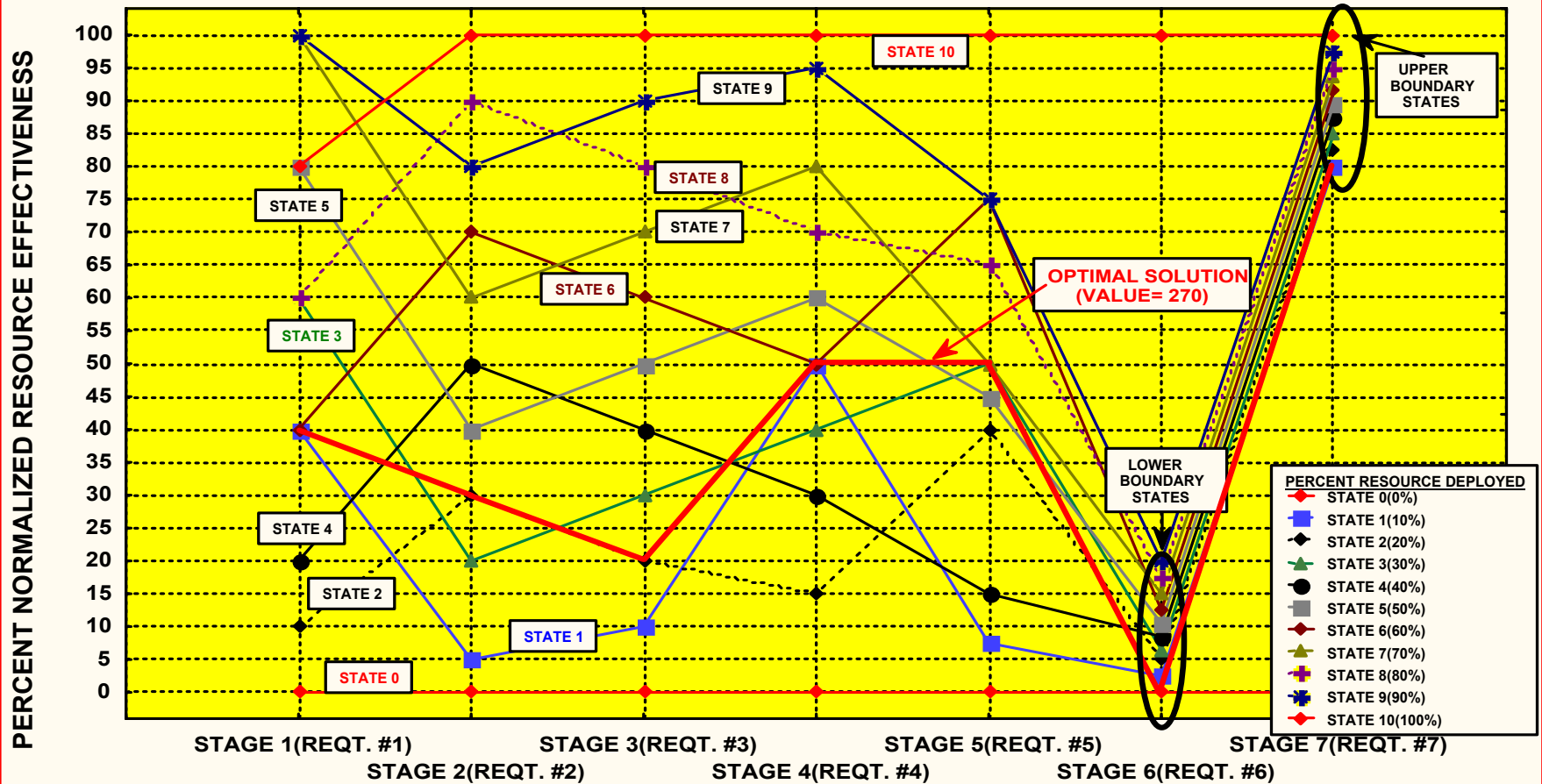
| NUMERIC VALUES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|----------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|
| | STATE_0 | STATE_1 | STATE_2 | STATE_3 | STATE_4 | STATE_5 | STATE_6 | STATE_7 | STATE_8 | STATE_9 | STATE_10 |
| STAGE_1 | 0.000 | 40.000 | 10.000 | 60.000 | 20.000 | 80.000 | 40.000 | 100.000 | 60.000 | 100.000 | 80.000 |
| STAGE_2 | 0.000 | 5.000 | 30.000 | 20.000 | 50.000 | 40.000 | 70.000 | 60.000 | 90.000 | 80.000 | 100.000 |
| STAGE_3 | 0.000 | 10.000 | 20.000 | 30.000 | 40.000 | 50.000 | 60.000 | 70.000 | 80.000 | 90.000 | 100.000 |
| STAGE_4 | 0.000 | 50.000 | 15.000 | 40.000 | 30.000 | 60.000 | 50.000 | 80.000 | 70.000 | 95.000 | 100.000 |
| STAGE_5 | 0.000 | 7.500 | 40.000 | 50.000 | 15.000 | 45.000 | 75.000 | 50.000 | 65.000 | 75.000 | 100.000 |
| STAGE_6 | 0.000 | 2.500 | 5.000 | 6.500 | 8.500 | 10.500 | 12.500 | 15.000 | 17.500 | 20.000 | 100.000 |
| STAGE_7 | 0.000 | 80.000 | 82.500 | 85.000 | 87.500 | 89.500 | 91.500 | 93.500 | 95.000 | 97.500 | 100.000 |

STATE VARIABLES = PERCENT OF RESOURCES (REQUIREMENTS) DEPLOYED
STAGES (ALTERNATIVES) = PROPOSED REQUIREMENTS
MATRIX ENTRIES = PERCENT EFFECTIVENESS

OBJECTIVE:
ALLOCATE REQUIREMENTS TO PERCENT (%) RESOURCES
DEPLOYED TO "MAXIMIZE" OVERALL EFFECTIVENESS.

Process Modeling

DR. AARON N. SILVER--PROCESS MODELING--DATA:SILTSTXT.STA
STAGE DIAGRAM--FILE#:SILTST6A.STG--SEPTEMBER 10, 2001



Process Modeling

PROCESS MODELING--DR. AARON N. SILVER--DATA (SNNTST9X.STA)
REGRESSION ANALYSIS--FILE#:SNNTST01.STG--OCTOBER 6, 2001

STAGE #1 --NORMALIZED PERCENT EFFECTIVENESS

