# Disk Subsystem Capacity Management, Based on Business Drivers, I/O Performance Metrics and MASF

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# Introduction: Environment

- Capital One
  - 6th largest card issuer in the United States
  - Capital One to S&P 500 in 1998
  - Fortune 500 company starting in 2000
  - Managed loans at $71.8 billion
  - Accounts at 46.7 million
  - CIO 100 Award "Master of the Customer Connection"
  - Information Week "Innovation 100" Award Winner
  - ComputerWorld "Top 100 places to work in IT"

# The Capacity Management service

- ~1000 servers of different platforms such as
  - UNIX/Linux
  - NT/W2K
  - Tandem
  - Unisys
  - MVS
- Capacity of "Capacity Management" environment and SLA
  - a relatively small 4-way Unix server (ServerP) and several large SAS based applications should
  - provide daily web based reports of capacity and performance issues by **8 am**

## Capacity Issue:

the Capacity Management System
needed to resolve its own capacity problem!

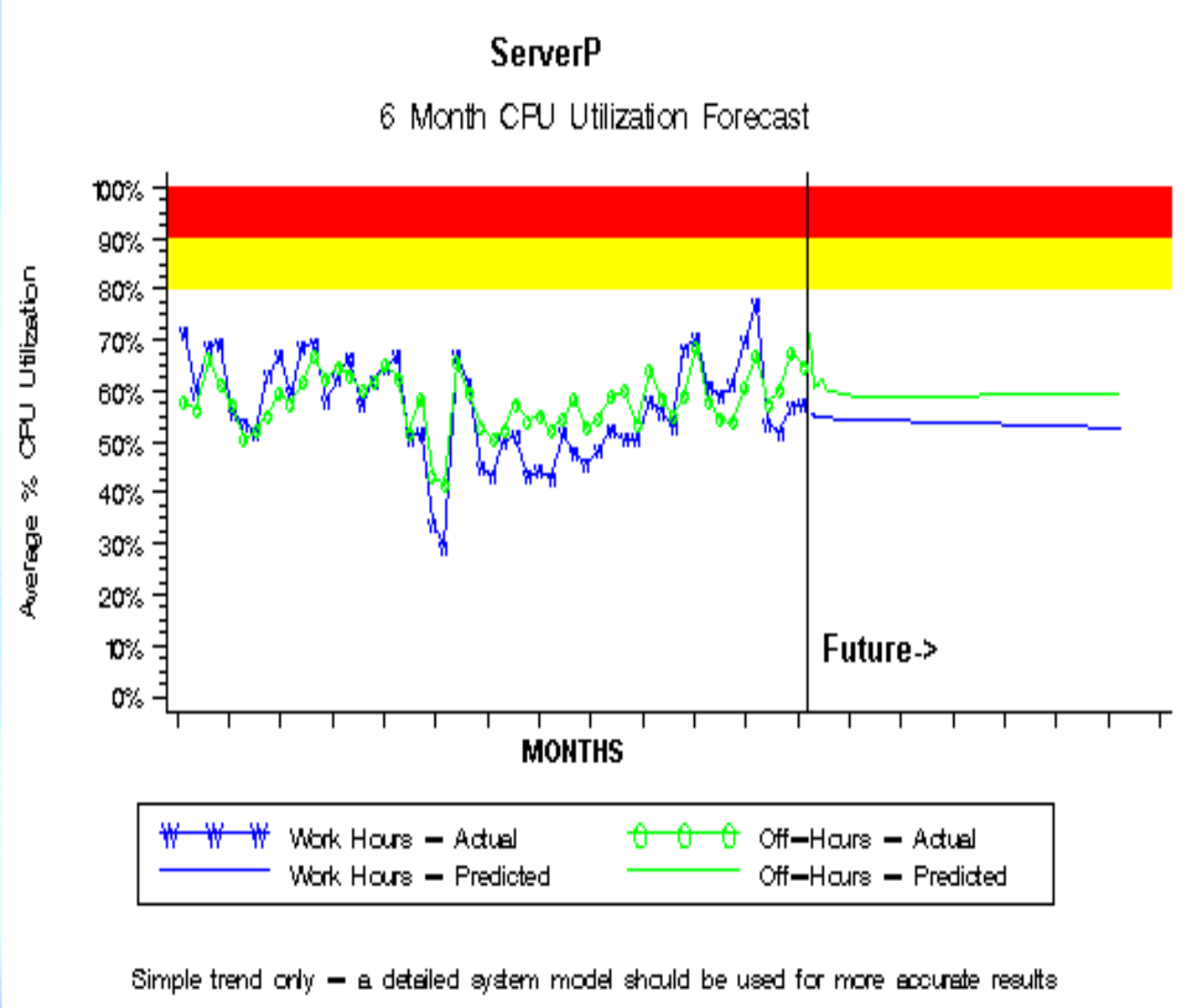
- SLA was broken, and the Capacity Planning web site was ready after **9 am**.
- Main reason:

  the growth in the number of servers.
- Main question:

  what subsystem needs to be upgraded?

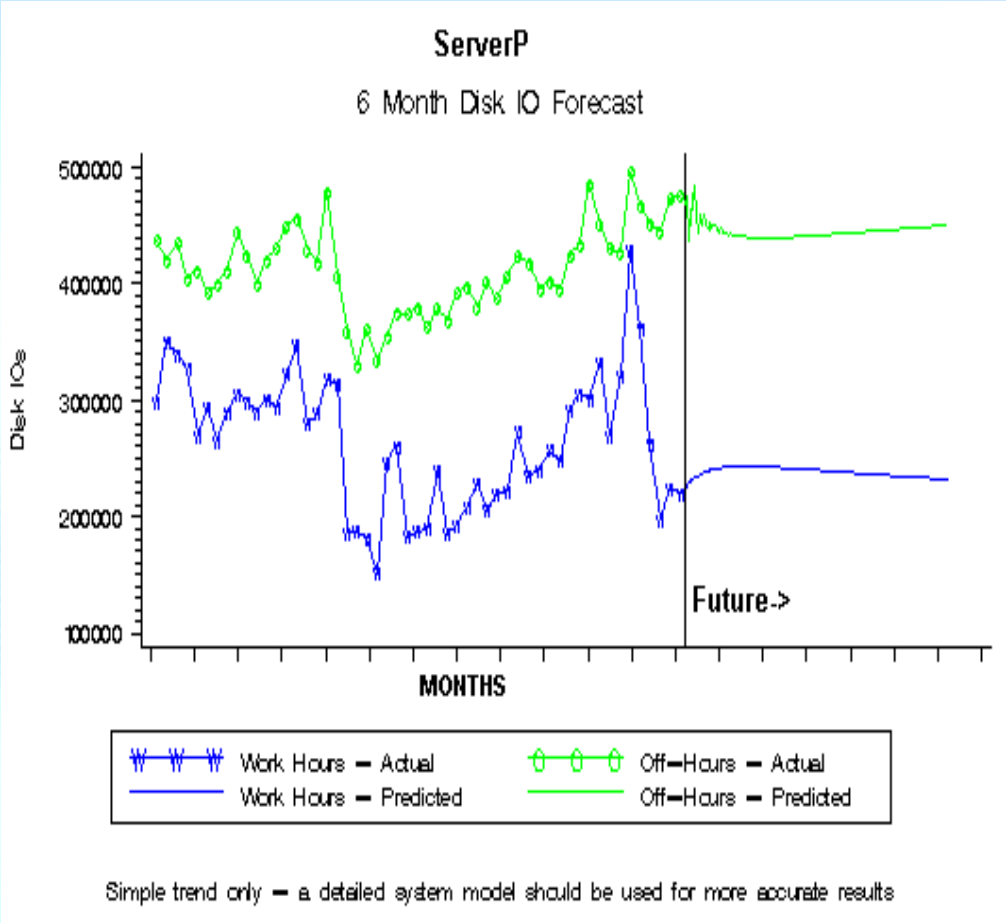
# CPUs?

Before a “recent” upgrade the metric had reached only 80% and based on simple trend analysis, no capacity problem would occur for several months.

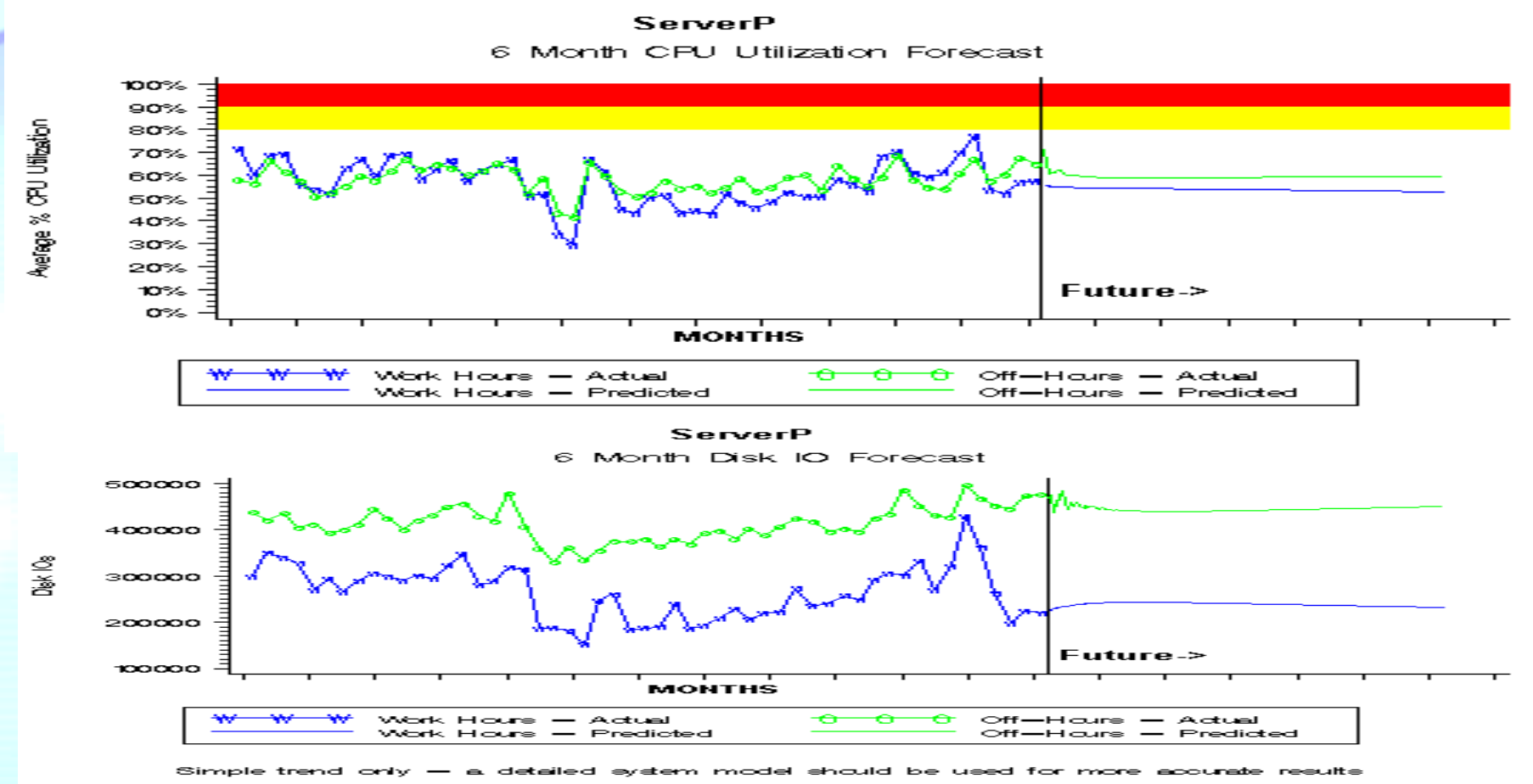


# DISK Subsystem ?

- SAS job is an I/O intensive workload and as shown on this chart, the Disk I/O metric had been growing as well
- The metric does not have a threshold, so, it's very hard to say this is a Disk subsystem capacity issue



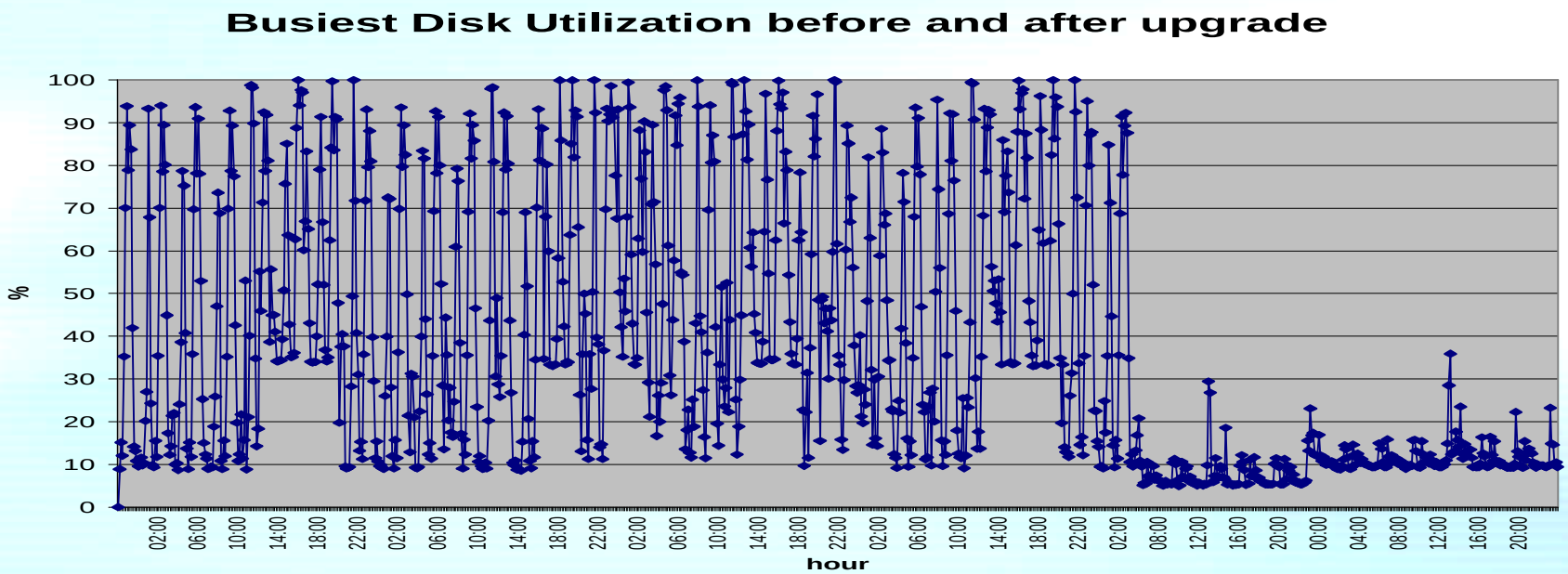
# Which subsystem was upgraded?




Both charts show that an upgrade has happened and as a result, both metrics have dropped.

# “Busiest Disk utilization” (“Disk Busy” )

HP MeasureWare: “*the percentage of time during the interval that the busiest disk device had I/O in progress from the point of view of the Operating System.*”




## Which subsystem was upgraded?

Indeed, older **disk** devices were **replaced** with faster RAID ones!

# The Presentation Objective:

**This presentation is an overview of Disk Subsystem metrics used for Capacity Management of the Capital One's large multi-platform server farm as well as discussions of how to use them to produce meaningful forecasts, simple modeling and statistical analysis.**

# Plan of the presentation:

- Introduction/Case Study - ***done***
- Disk Subsystem Metrics Overview
- Disk Metric Trend Analysis and Forecast
- Overall Disk I/O Capacity Estimation
- Statistical Analysis of Disk Performance Data
- SUMMARY/ References

# Disk Subsystem Metrics Overview

- **File System Utilization**

  – *Problem:* Capacity Management environment may not have the capacity to monitor and report capacity problems about all File Systems (hundred thousands).

  – *Bad solution*: GLB_FS_SPACE_UTIL_PEAK (similar to "Disk Busy") UNIX performance metric, which is

  "*the percentage of occupied disk space to total disk space for the fullest file system found during the interval.*"

  BUT (!) The file system that has OS or other UNIX system files is always "almost full" !

# Disk Subsystem Metrics Overview

- *Better solution: Concord* eHeallth performance monitor system has interesting metric "**System Health Index**" which is the sum of five components (variables):

  - **SYSTEM**, which reports a CPU imbalance problem;
  - **MEMOR**Y, which is exceeding some memory utilization threshold or reflects some paging and/or swapping problems;
  - **CPU**, which is exceeding some utilization threshold;
  - **COMM**., which reports network errors or exceeding some network volume thresholds;
  - And **STORAGE**, which might be a combination of

    a. Exceeding user partition utilization threshold;

    b. Exceeding system partition utilization threshold;

    c. File cache miss rate, Allocation failures and

    d. Disk I/O faults problem that can add additional points to this Health Index component.



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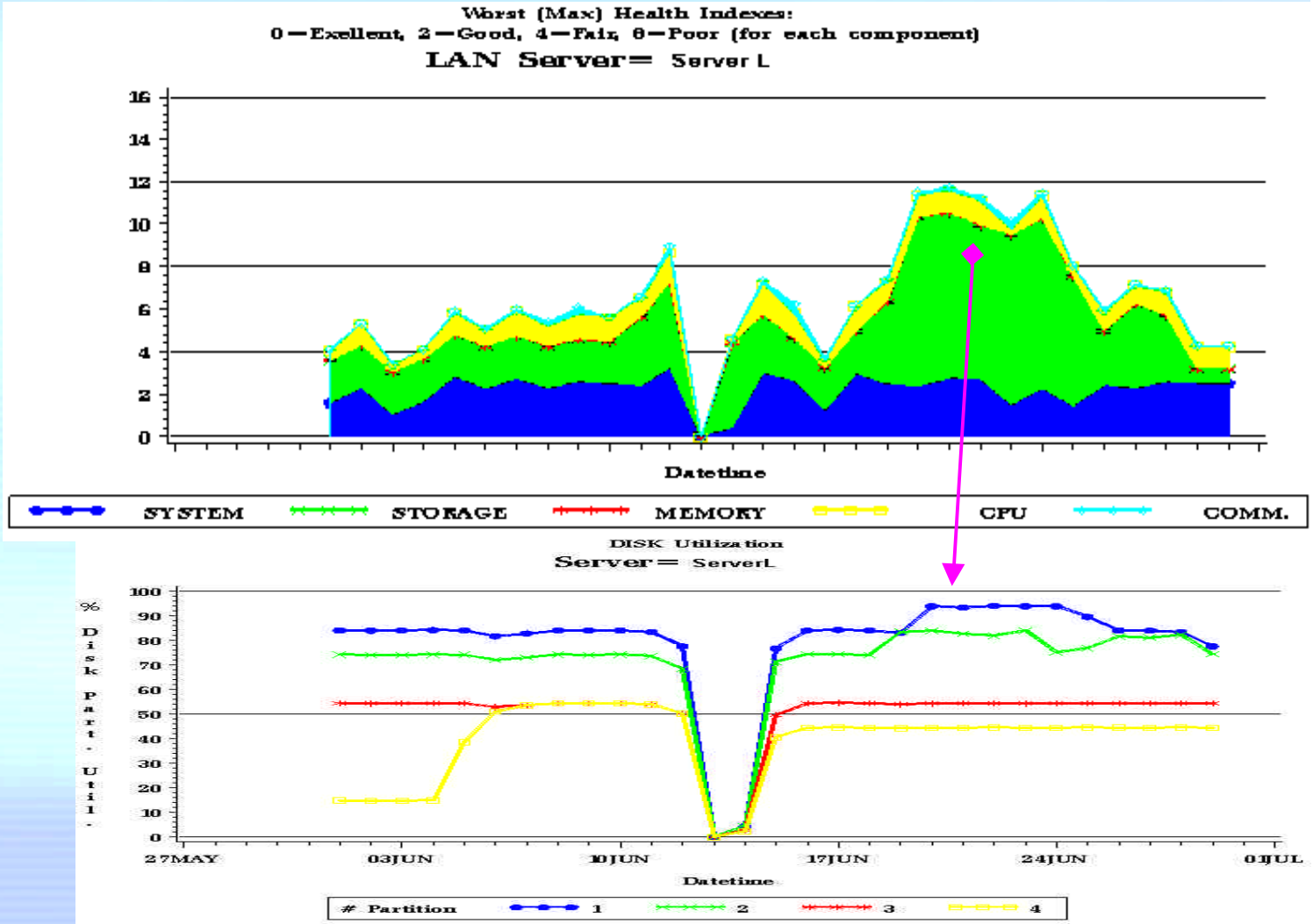
# Disk Subsystem Metrics Overview

- Example of "**System Health Index**" from *Concord* eHeallth:

- **STORAGE** component has the biggest contribution and demonstrates some bad trending.

- **partitions** #1 and #2 were highly utilized and caused a Health Index increase.



# Disk Subsystem Metrics Overview

- *BMC Patrol Perceive* about **File Systems metrics**:
  - Percent of file system that is full;
  - Size of file system in megabytes;
  - Measure of inodes used in the file system;
  - Number of inodes in the file system;
  - Amount of free space in the file system
  - Number of free inodes in the file system
  - Amount of file system space available that is allocated for general use

# Disk Subsystem Metrics Overview

- *BMC Patrol Perceive* report example:

Good combination is utilization and actual size of the file systems

Indeed,

1% free space of 100 GB disk is equal to

10% free space of a 10 GB disk.

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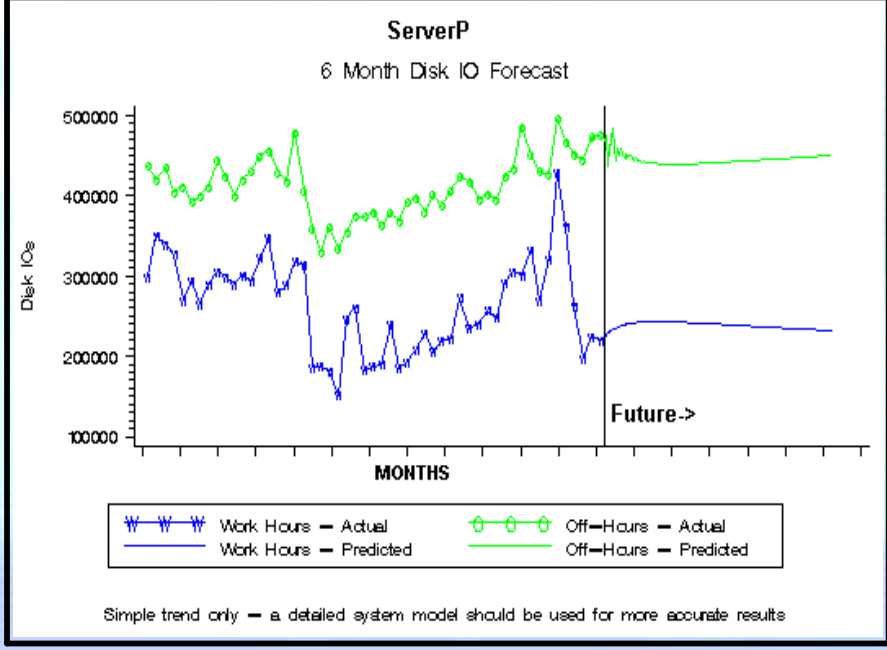
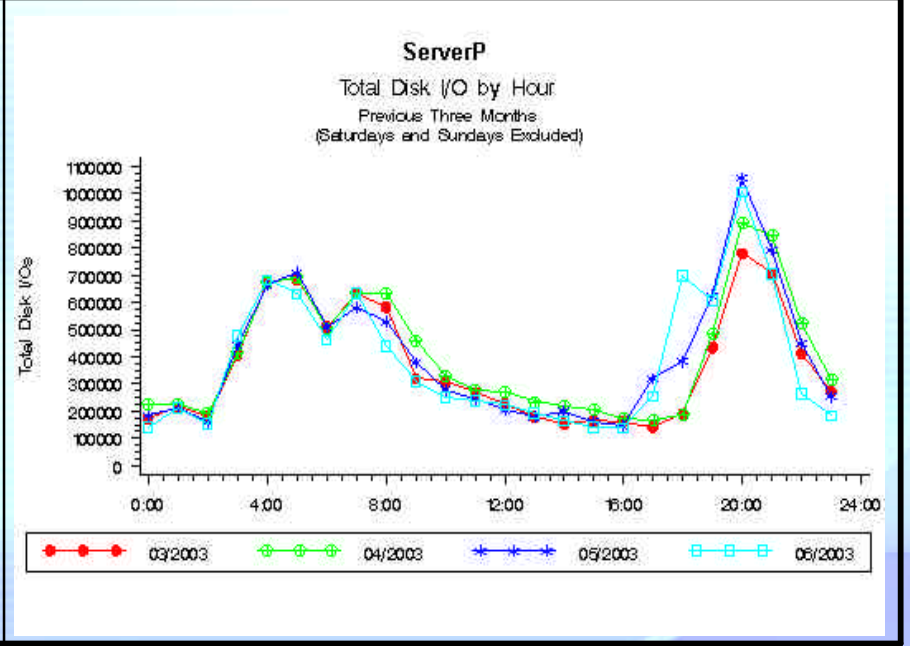
# Disk Subsystem Metrics Overview

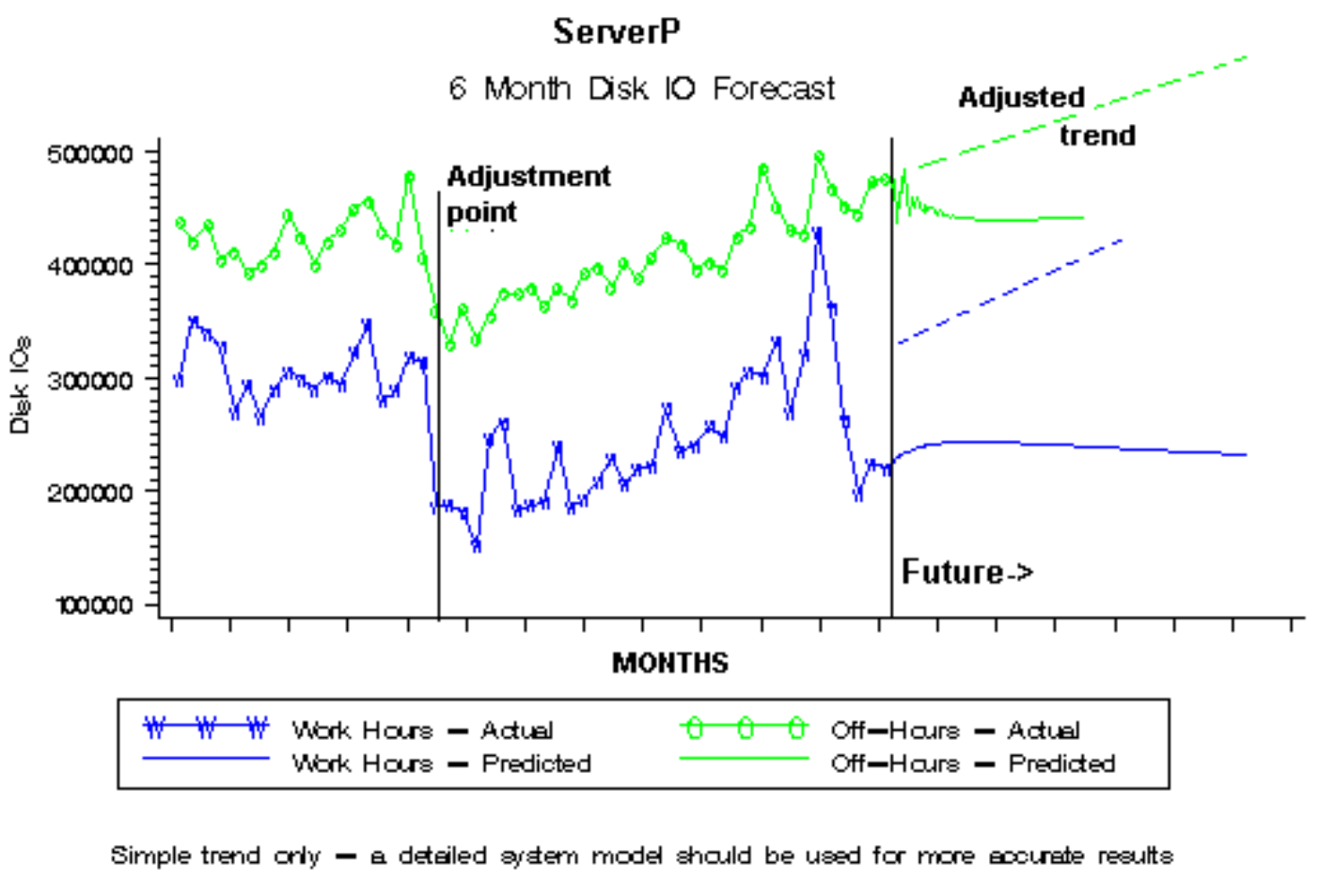
- **Disk I/O rate** is the number of physical I/Os per second during the interval.

| | |
|---|---|
| Disk I/O rate trend for off- and work-hours and standard SAS "forecast" procedure based on one of the "time series" algorithms | 24-hour profile grouped by nearest month hourly averages. Good picture to balance workload during the day |
|  |  |

# Disk Metric Trend Analysis and Forecast

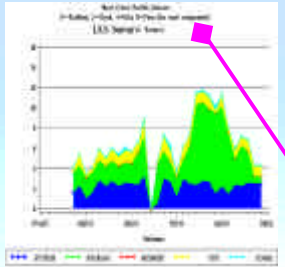
- More realistic future **Disk I/O rate** trend example:

SAS scripts should be adjustable to take in consideration upgrades, workload shifts or consolidations



# Disk Metric Trend Analysis and Forecast

- **Health Index** trend analysis:



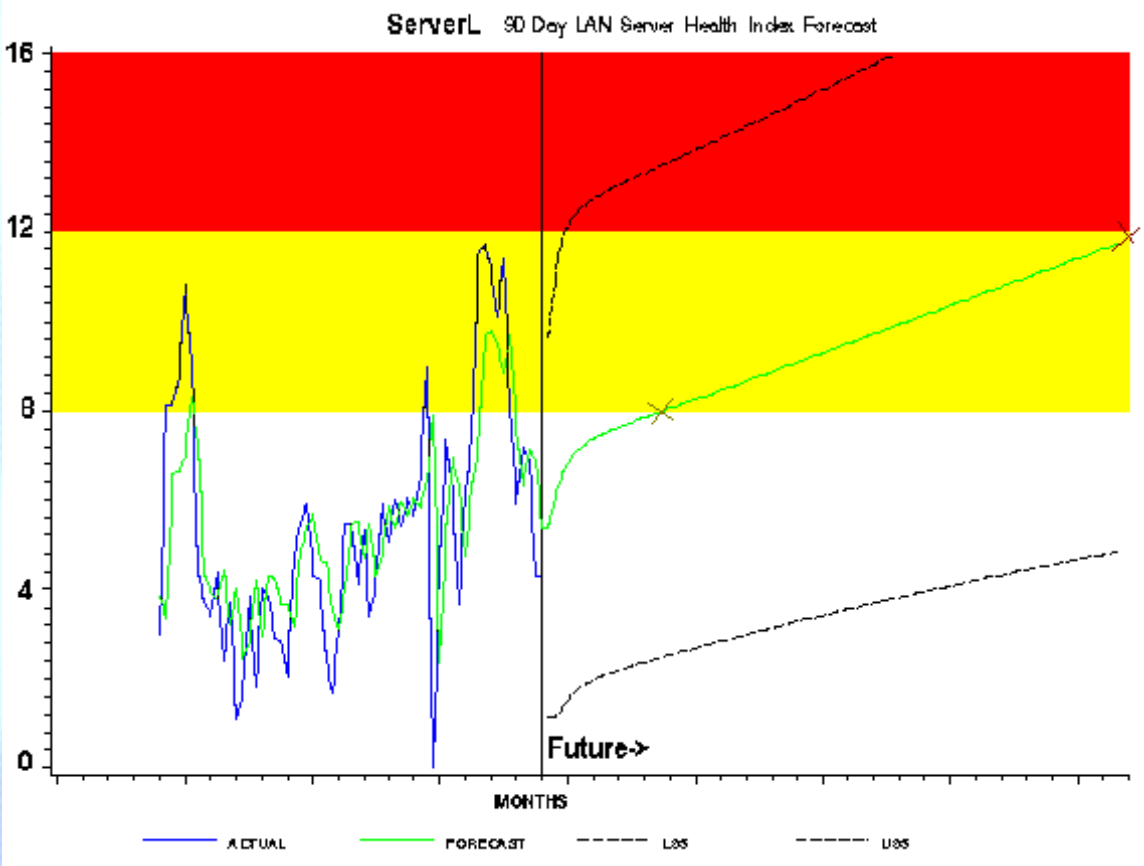
*Big advantage*:

– There is a real threshold

*Disadvantages:*

– The Disk subsystem is indirectly presented here;

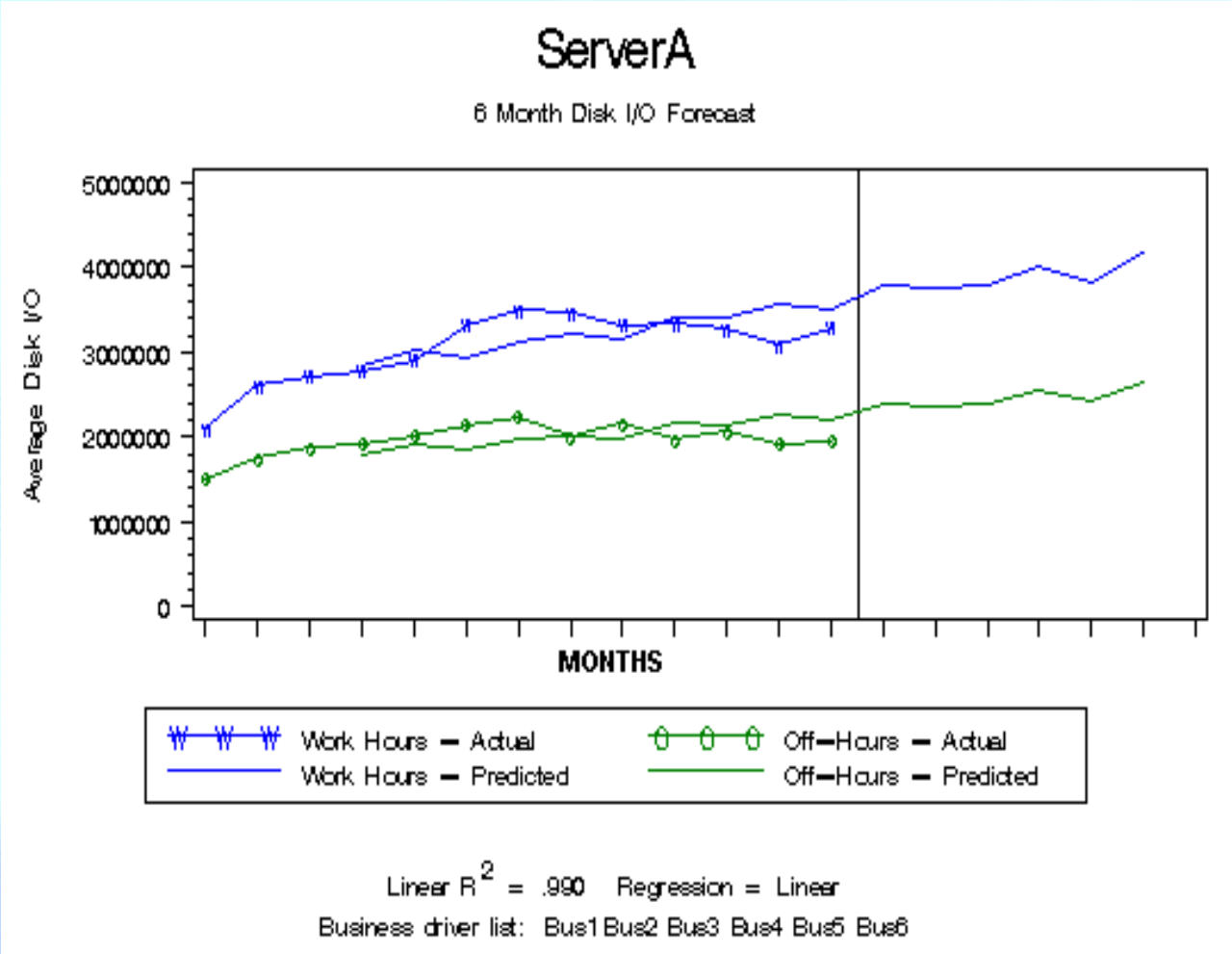
– The future trend tries to predict future problems of different subsystems and sounds very suspicious as an “apples to oranges” comparison



# Disk Metric Trend Analysis and Forecast

- A performance data vs. business driver **correlation analysis:**

**Take** monthly business driver data (historical and projected) from business units within the company, **configure** each server to one or more business drivers, and **perform** SAS multivariate regressions against CPU utilization or disk I/O !

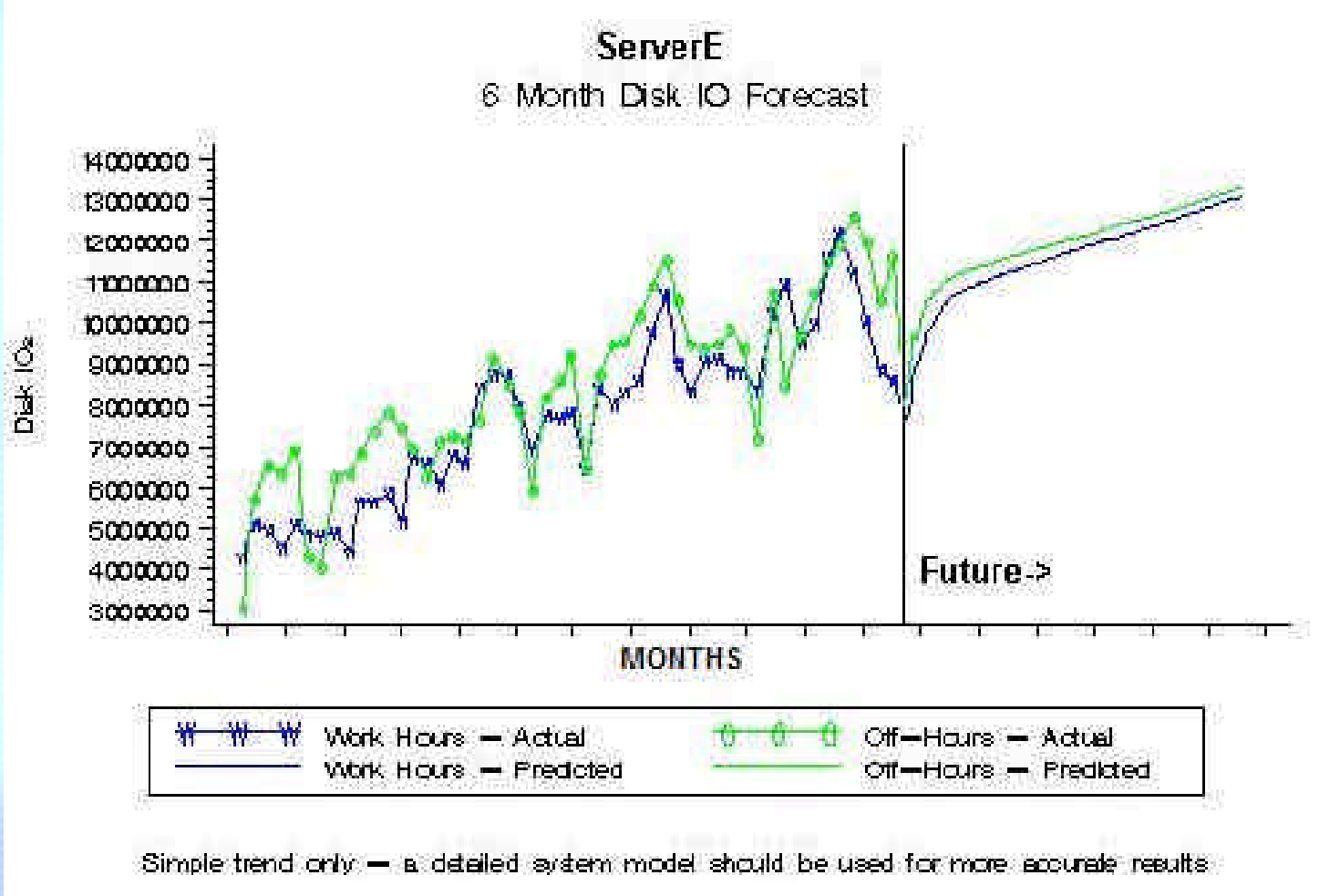


# Overall Disk I/O Capacity Estimation

- Could we have a threshold for Disk I/O trend chart?

Based on HP MeasureWare DISK level data,

there is the possibility to estimate overall disk subsystem I/O capacity.



# Overall Disk I/O Capacity Estimation

For the sample interval (5 min) HP MeasureWare log file had DISK utilization equaled to BYDSK_UTIL,

| Time | DEVICE_NAME | BYDSK_UTIL % | BYDSK_PHYS_IO_RATE IO/sec | DISK Capacity IO/sec |
|---|---|---|---|---|
| 11:35 | 7/0/0.8.0.3.1.4.6 | 63.0 | 30.9 | 49.05 |
| 11:35 | 6/0/0.8.0.3.1.0.6 | 60.9 | 41.7 | 68.50 |
| 11:35 | … | … | … | … |

the rate of I/O was equaled BYDSK_PHYS_IO_RATE.

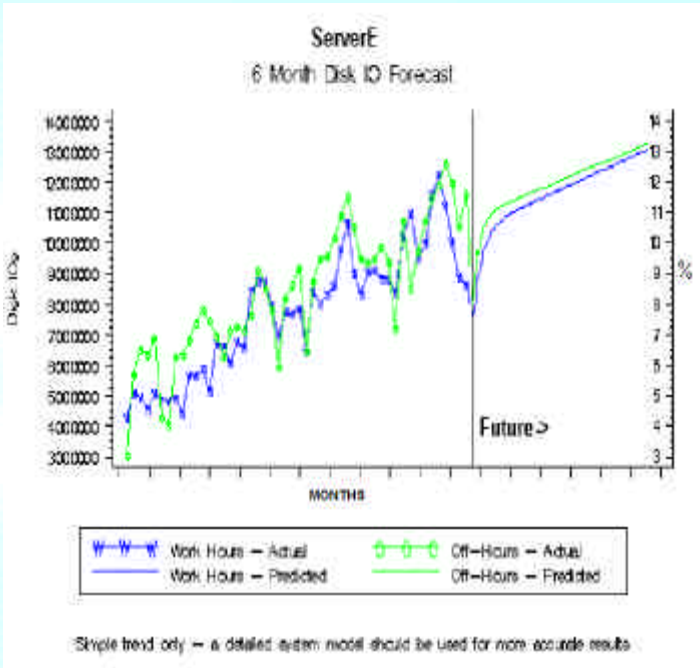
The maximum of the I/O rate which would be executed if the disk was 100% busy is:

**DISK Capacity (IO/sec) =**
BYDSK_PHYS_IO_RATE (IO/sec)
* 100 / BYDSK_UTIL (%)

Disclaimer: It is a very simple linear model and does not take in consideration the DISK queue and controller cache usage

# Overall Disk I/O Capacity Estimation

Yes, we have a I/O rate threshold for each Disk,
but how to make the estimation across all Disks?




**I/O Capacity: Available(calculated)**

| | *Sum of ALL Disks IO Capacity IO/sec* |
|---|---|
| ***Time*** | ***Total*** |
| 11:35 | 33,402.75 |
| ... | ... |
| 12:30 | ***37,172.06*** |
| 12:35 | 25,957.33 |
| ***Max capacity IO/sec*** | ***37,172.06*** |
| ***Max capacity IO/hour*** | ***133,819,406.86*** |

**I/O Capacity: Used(The actual measured I/O rate)**

| | *Sum of ServerE: BYDSK_PHYS_IO_RATE IO/sec* |
|---|---|
| ***Time*** | ***Total*** |
| 11:35 | ***2,460.20*** |
| ... | ... |
| 12:30 | 1605.79 |
| 12:35 | 2101.39 |
| ***Max Actual IO/sec*** | ***2,460.20*** |
| ***MAX Actual IO/hour*** | ***8,856,719.97*** |

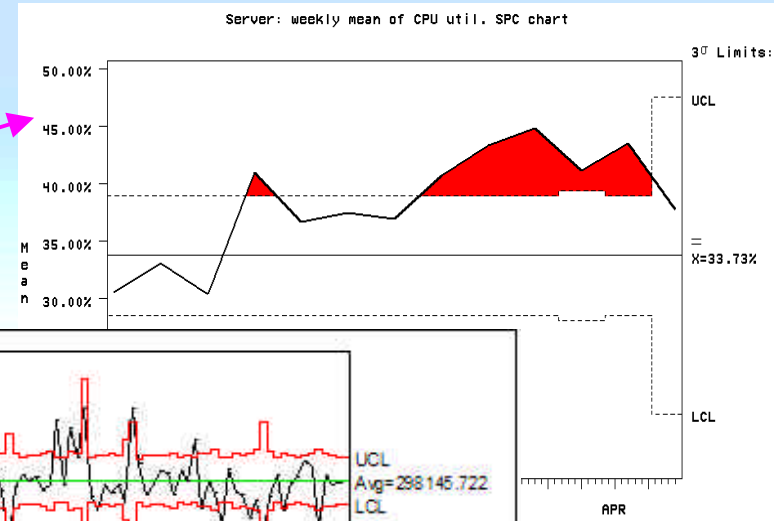
Finally ServerE DISK IO
CAPACITY utilization is *(Max Actual IO/hour)*100/(Max capacity IO/hour)=* *6.62%*

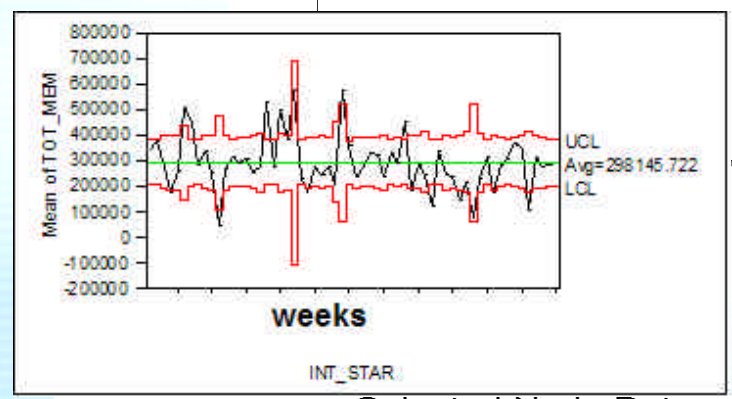
# Statistical Analysis of Disk Performance Data

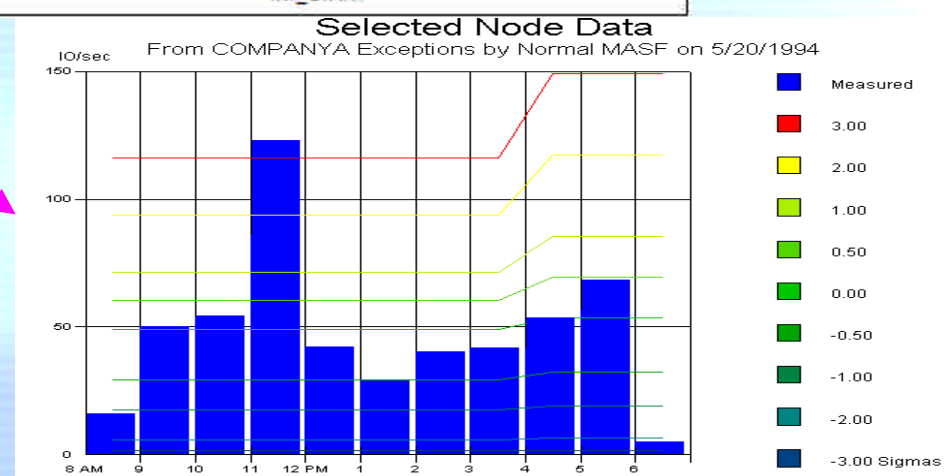
- Another way to build a dynamic threshold of Disk I/O rate is SEDS - Statistical Exception Detection System based on Multivariate Adaptive Statistical Filtering (MASF) technique.
- SEDS is used for automatically scanning through large volumes of performance data and identifying measurements that differ significantly from their expected values.
- MASF is extension of Statistical Process Control or (Quality Control) which was developed by Walter Shewhart of Bell Telephone Laboratories in the 1920s.
- MASF procedure was designed and presented in CMG by BGS Systems, Inc. in 1995.
- SEDS is developed by this author and presented as the best paper in CMG 2002.

# Statistical Analysis of Disk Performance Data

- Review of the existing tools:
  - **SAS/QC** (Quality Control);
  - **JMP** from SAS;
  - **BEZsystems**
    for Oracle and Teradata;
  - **Concord eHealth** – DFN
    (Deviation From Normal)
  - The Patrol Perform and Predict tool
    from **BMC software**;



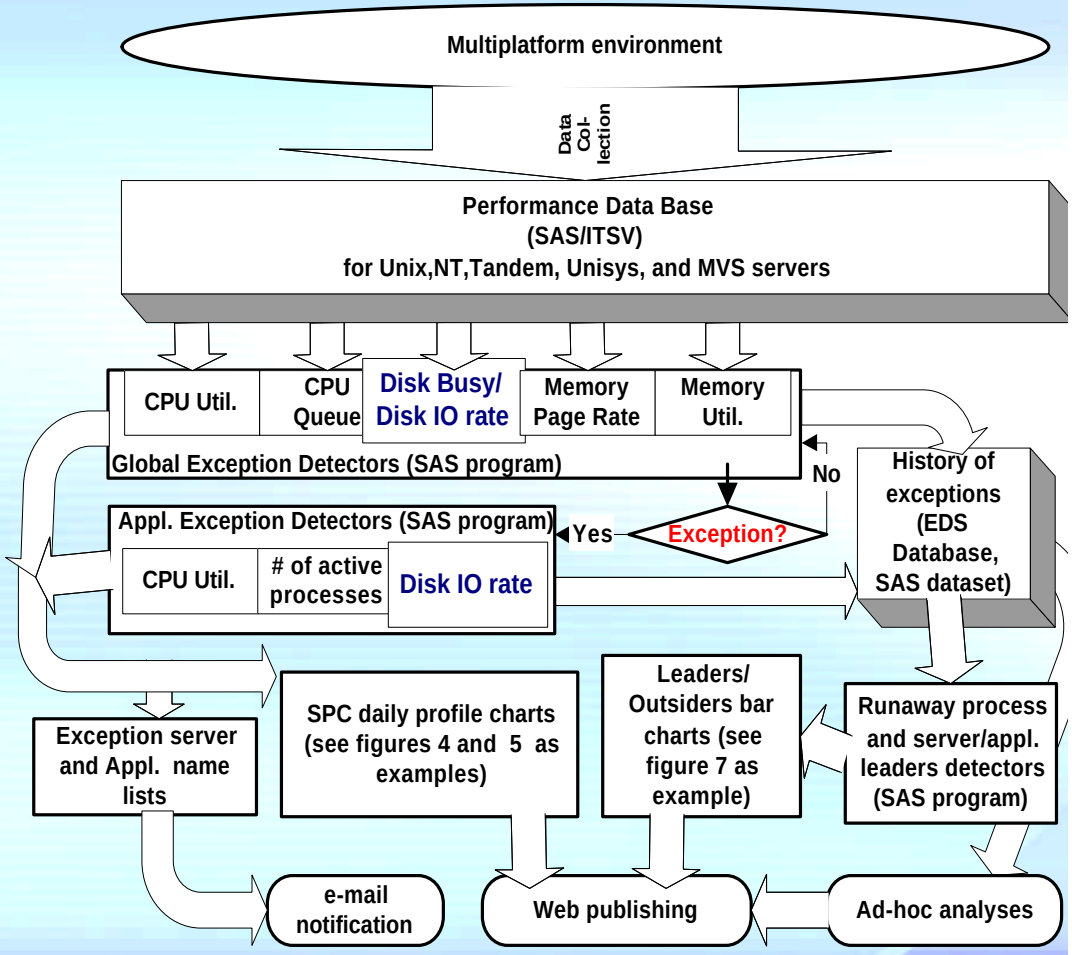




The common output is ***Control charts*** for monitoring variations in process under statistical control

# Statistical Analysis of Disk Performance Data

- SEDS structure:
  - Exception detectors for the most important metrics including Busiest Disk Utilization and Disk I/O Rate;
  - SEDS Database with history of exceptions;
  - statistical process control daily profile chart generator;
  - exception server name list generator;
  - Leader/Outsider servers detector and detector of runaway processes; and
  - Leaders/Outsiders bar charts generator.



# Statistical Analysis of Disk Performance Data

- SEDS implementation:
  - **Performance database (PDB):** SAS/ITSV; BMC Visualiser Database
  - **Home made programs:** SAS 8.2; Unix scripting (awk/sed/perl); VisualBasic.NET/SQL;
  - **Reporting:** Intranet web server; HTML, Email
  - **Special features:**

    *a*. Two level exception estimation: Global and Application.

    *b*. statistical exception alerts (e-mail notification);

    *c*. spetial database to keep history of exceptions
  - **The rules to avoid taking into consideration:**

    *a*. noise (collector errors, runaway processes);

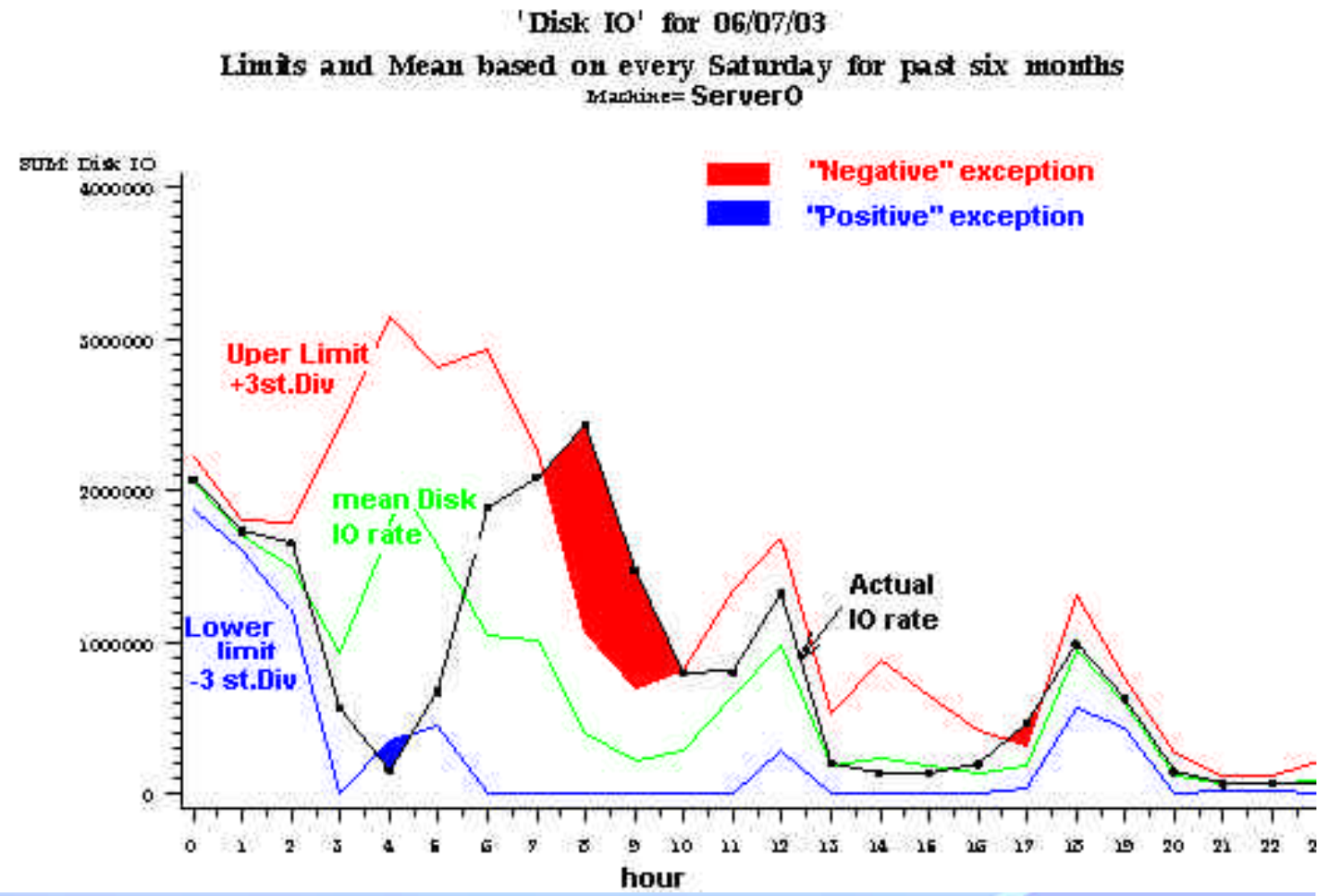
    *b*. insignificant exceptions (like slight increases of workloads for underutilized servers);

    *c*. other insignificant patterns, based on the analyst's interpretation.

# Statistical Analysis of Disk Performance Data

- DISK I/O Control Chart for Web Publishing:

The full **"7 days X 24 hours"** adaptive filtering policy is applied to calculate the average, upper, and lower statistical limits of a particular metric for each weekday for the past six months.

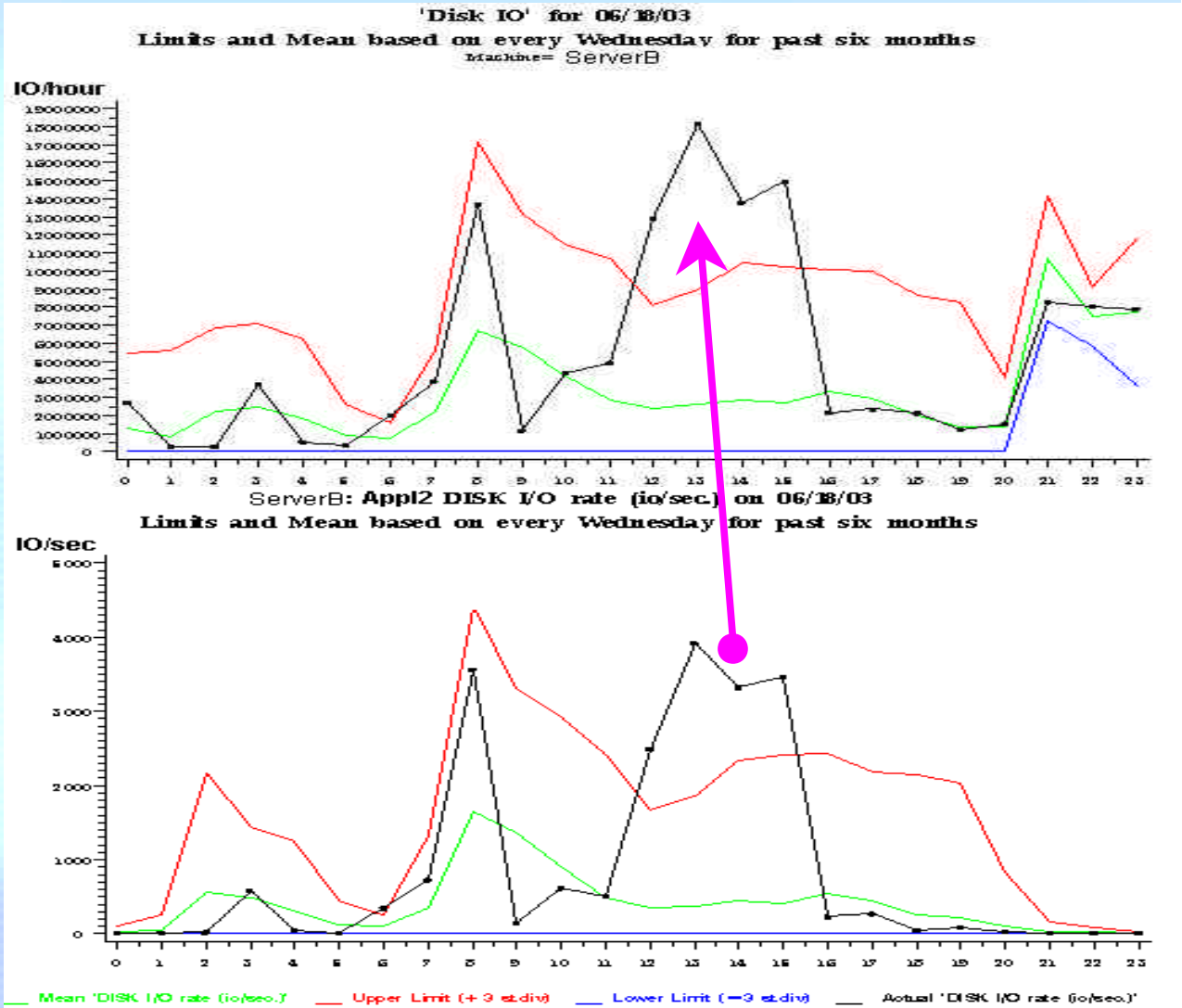


# Statistical Analysis of Disk Performance Data

- Application Level DISK I/O Control Charts

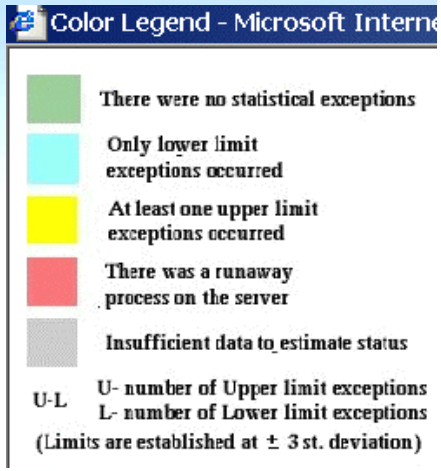
  - SEDS captured a Disk I/O rate exception at about 4:00 PM on **ServerB**,

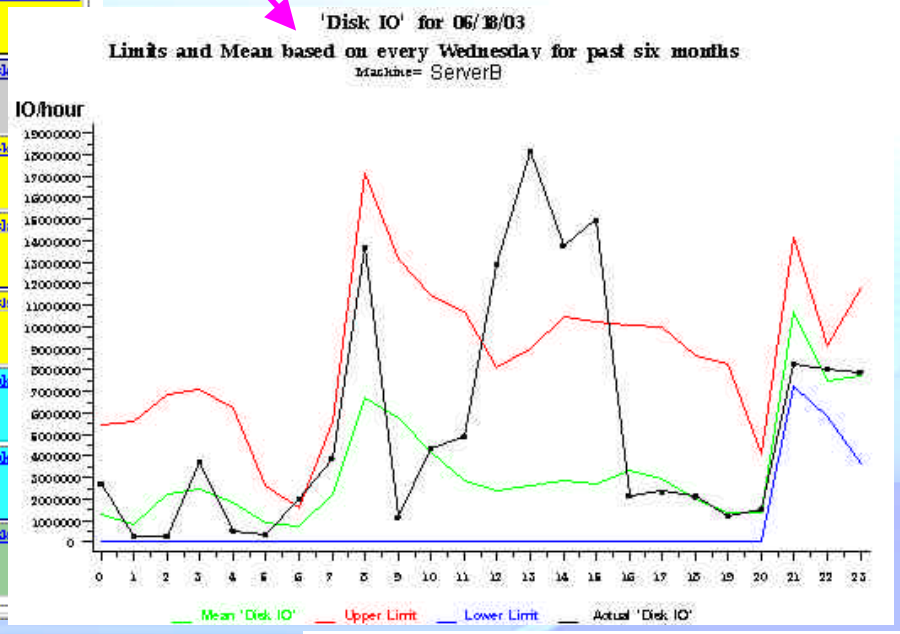
  - and the Application detector found that the Workload **"Appl2"** had an exception as well.



# Statistical Analysis of Disk Performance Data

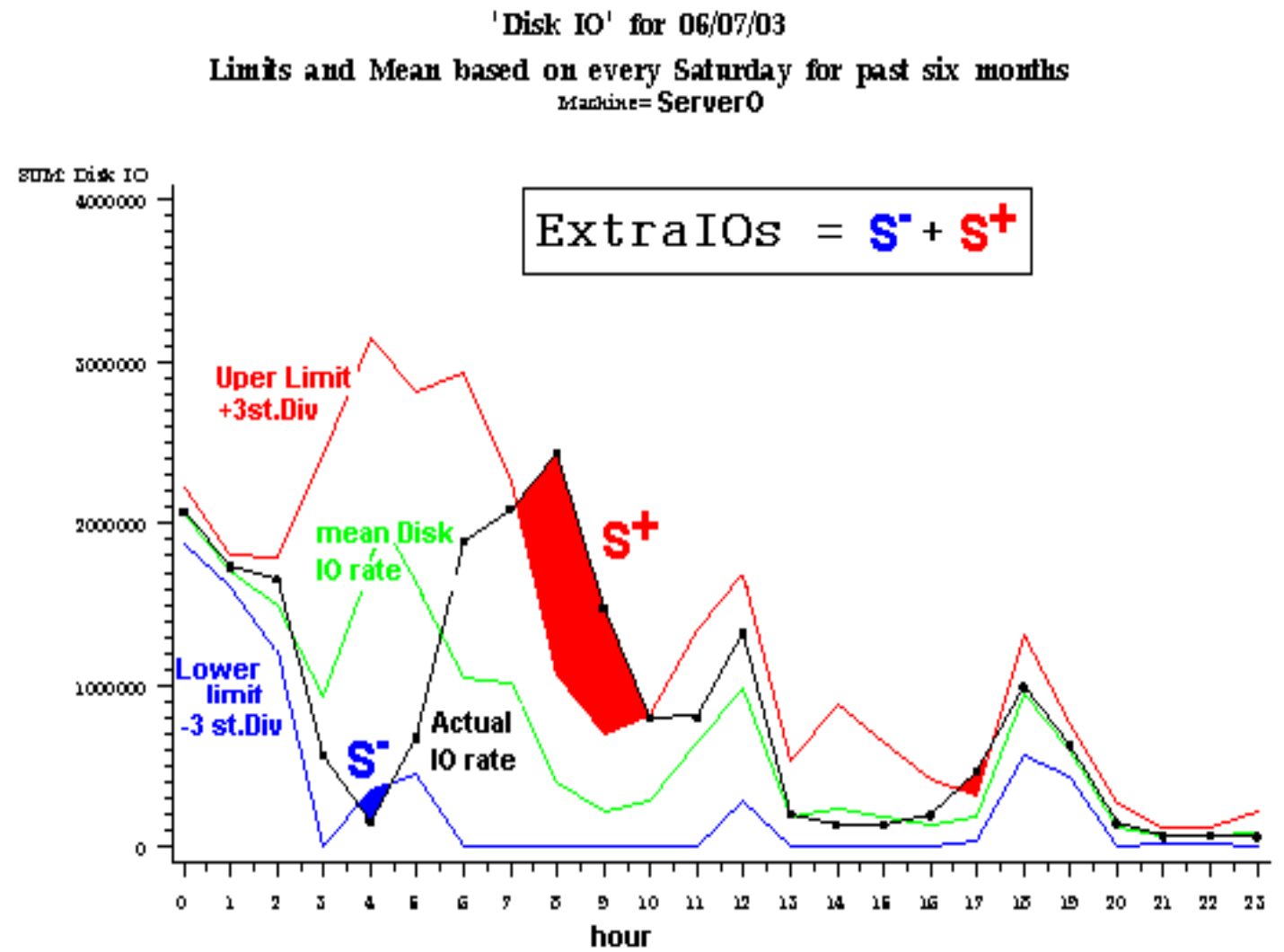

- System performance daily web report based on EDS database



# Statistical Analysis of Disk Performance Data

- **ExtraVolume** is the numeric estimation of the exception magnitude
  - It calculates **the area** between the limit curve and the actual data curve (for periods when the exceptions occurred).
  - **Physical meaning** is the number of I/Os the server has taken that exceeds a standard deviation.

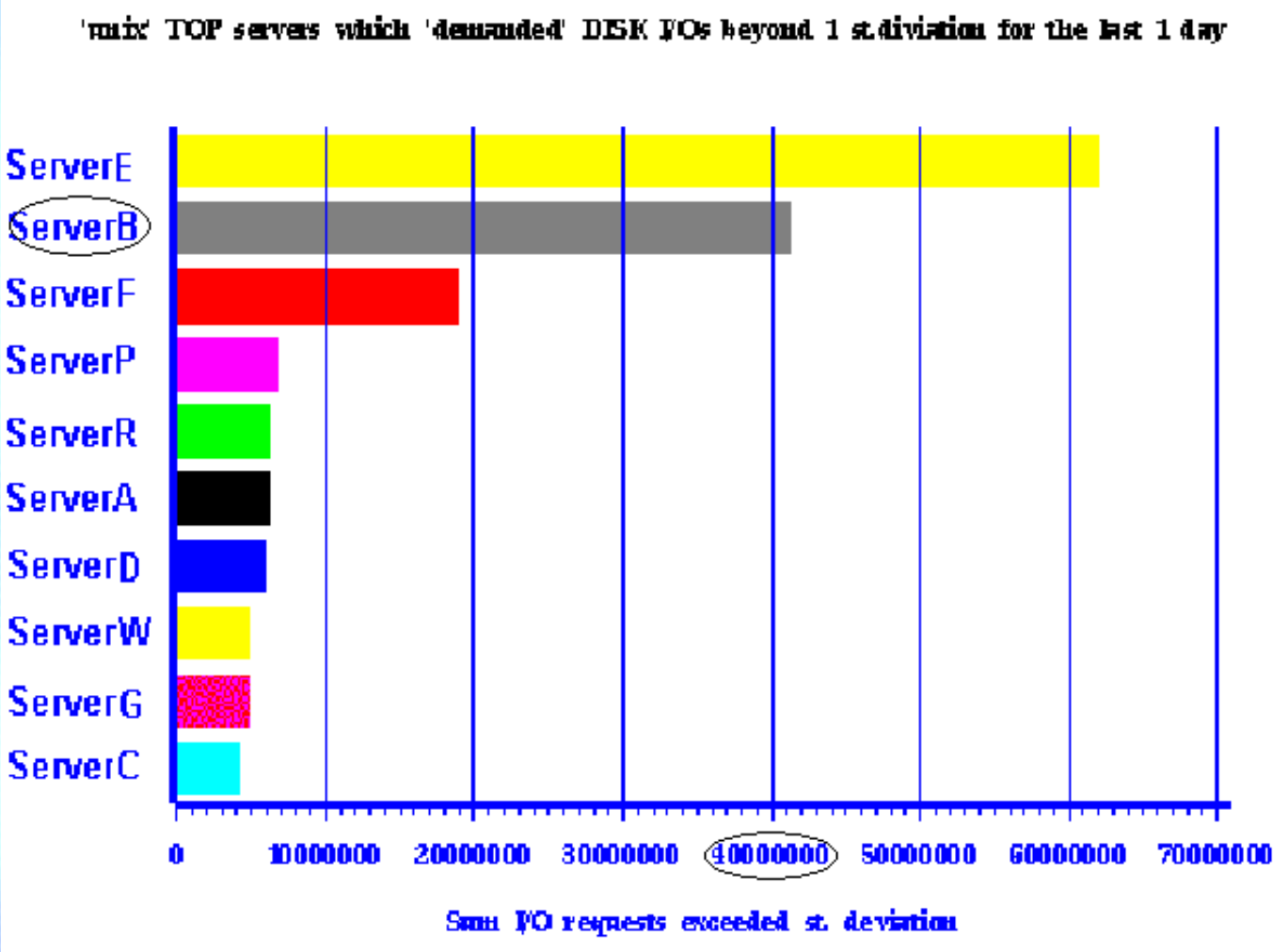


# Statistical Analysis of Disk Performance Data

- TOP I/Os Leaders Charts (ExtraIOs>0)

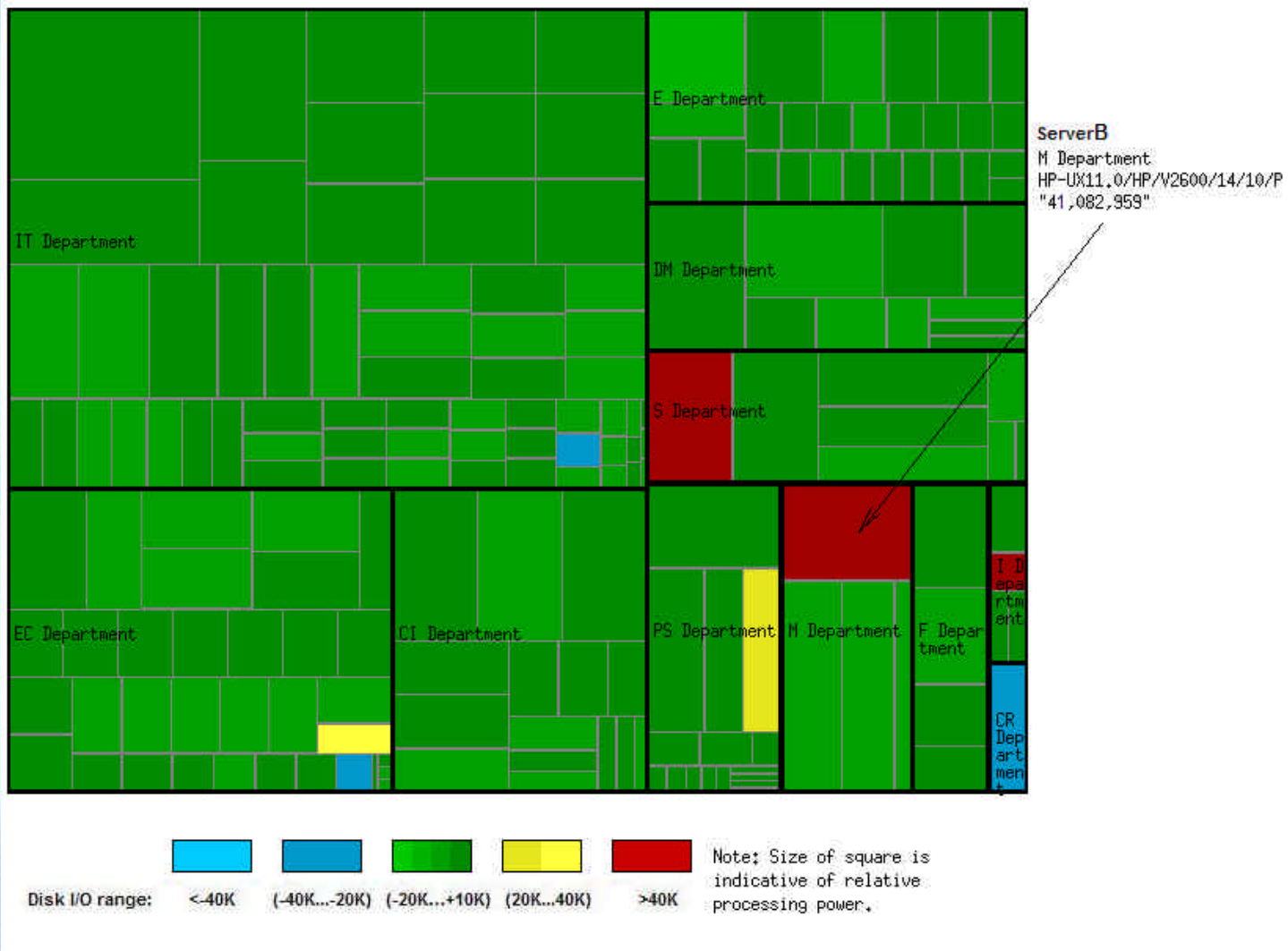
– The system automatically produces **ExtraIOs calculation** for the last day and records that in the SEDS database.

– This data is used for generating **Leaders/Outsiders charts** for the last day, last week, last month, and publishing the bar charts



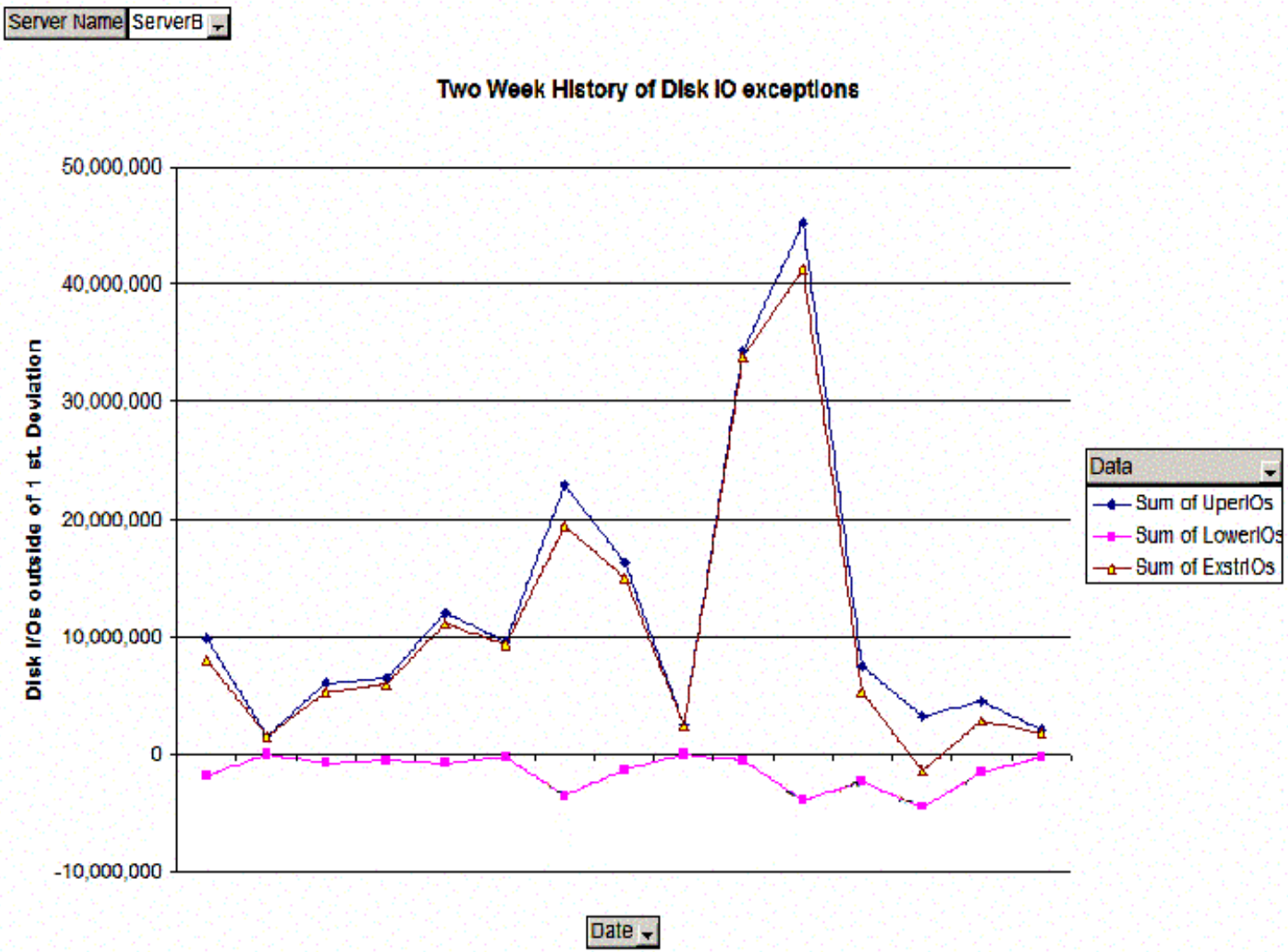
# Statistical Analysis of Disk Performance Data

- Overall company wide picture of all servers that had Disk I/O exceptions
  - The colored **"Treemap,"** or **"heat chart."** has been already used to publish an overall capacity status
  - SEDS produces the similar chart **for IO exceptions;** here the ServerB is presented as pretty large red box inside of "M Department", because the unusual I/O usage was bigger than 40,000,000



# Statistical Analysis of Disk Performance Data

- History of exceptions can give very interesting data for a trend analysis
  - This is **history of unusual Disk I/Os** on ServerB for the last two weeks.
  - The **disk performance issue was escalating** and the server fell into the "Top 10" server list and then the issue was addressed and resolved.



# SUMMARY

- **Understand the metrics.** There can be a large amount of data, from different sources. The Capacity Planner must first know which metrics are captured, and understand reporting and analysis nuances around the metrics.
- **Forecast demand.** This presentation has discussed the use of trend analysis and business driver based forecasting to predict future demand.
- Determine **capacity thresholds** for action. This presentation discusses the calculation of maximum I/O rates as well as a method using Statistical Process Control concepts.
- **Reporting.** This presentation gives examples of utilization and trend charts, exception reporting, “Top 10” reporting, and “Treemap” heat charts..

# References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# Thanks!

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