Performance Analysis for Process Improvement

Michael V. Petrovich

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Introduction

Warning:

This material may cause a paradigm shift.

Should you not wish your paradigm shifted you may want to leave at this time.

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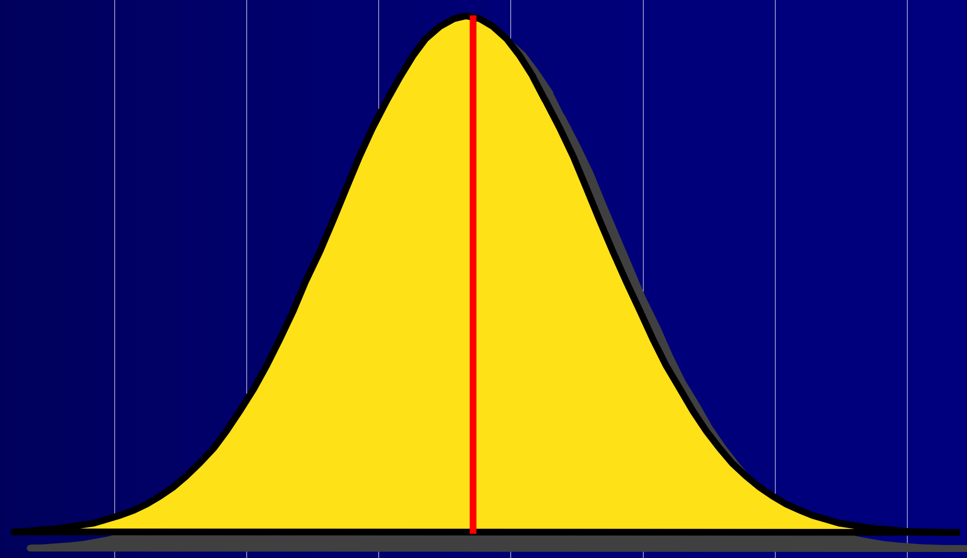
Presentation Outline

- Introduction
- Sampling
- Process Performance Measures
- Process Performance Analysis
- Example

Quality Goals

- The elimination of nonconformance
- The minimization of variation around appropriate targets



Quality Goal Questions

- How well are these quality goals being realized?
- What must be done to improve?

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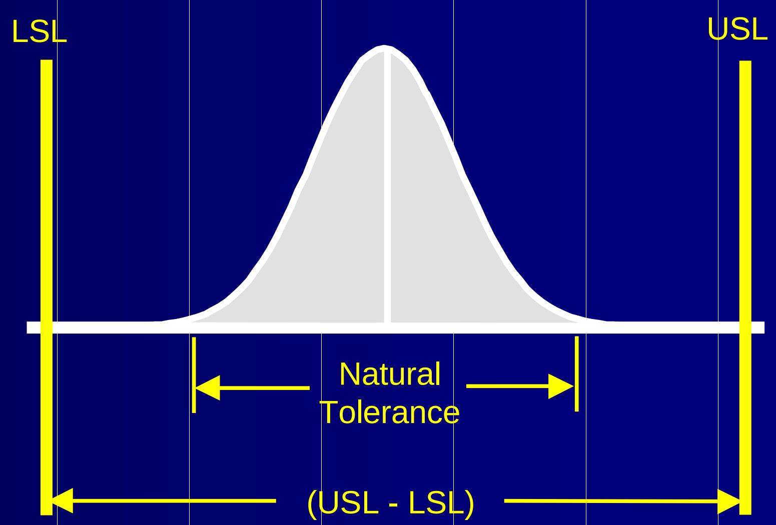
Traditional Approach

- Establish statistical control of a process
- Determine the underlying process distribution
- Conduct a Process Capability Analysis



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Scenario #1

- A Plastic Lid Manufacturer
  - 40 molding machines
  - 54 Tools per molder
  - Tools are replaced every few weeks
  - Tool-to-Tool Differences found
  - Differences from Raw Material batches
  - Variation from maintenance cycles, startup periods, and operator adjustments

Scenario #2

- A Metal Crown Company
  - Eight Presses
  - Each Press Contains 22 dies
  - Differences exist die-to-die and press-to-press
  - The process exhibits tool wear
  - Slight fluctuations are observed with lot-to-lot changes in steel

Scenario #3

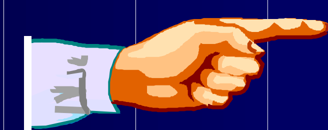
- An Aluminum Can Manufacturer
  - Two Lines in One plant
  - Each Line contains 16 stations
  - Station-to-station differences are found
  - This process also undergoes tool wear
  - Perfect through-time stability (or control) is not observed in many of the stations

Conclusions

- Traditional capability methods are inadequate in these situations
- Without statistical control, capability assessment cannot be made
- The number of process streams yields a nightmare to mathematically model
- Practitioners still need a means of assessing their process

Performance Measures

- In recent years “Process Performance Measures” have gained popularity

Capability		Performance
C_{pk}		P_{pk}
C_p		P_p
C_{pm}		P_{pm}

Process Performance Measures Differ from Capability Measures

- Statistical control not required for analysis
- Common and special causes may both be present
- Do not consider distributional shape
- Measure past performance only
- Do not predict the future

Process Performance Measures

- Assess total observed variation produced during a particular time period
- Can be used as validation measures for process improvement

Process Performance Analysis

- Uses Process Performance Measures, descriptive measures, and graphical techniques to study processes

PPA

With Process Performance Analysis

- Assess processes before statistical control is achieved
- Determine sources of process loss
- Make comparisons among characteristics, products, plants, and suppliers
- Determine control and improvement priorities
- Assess results of process improvement efforts

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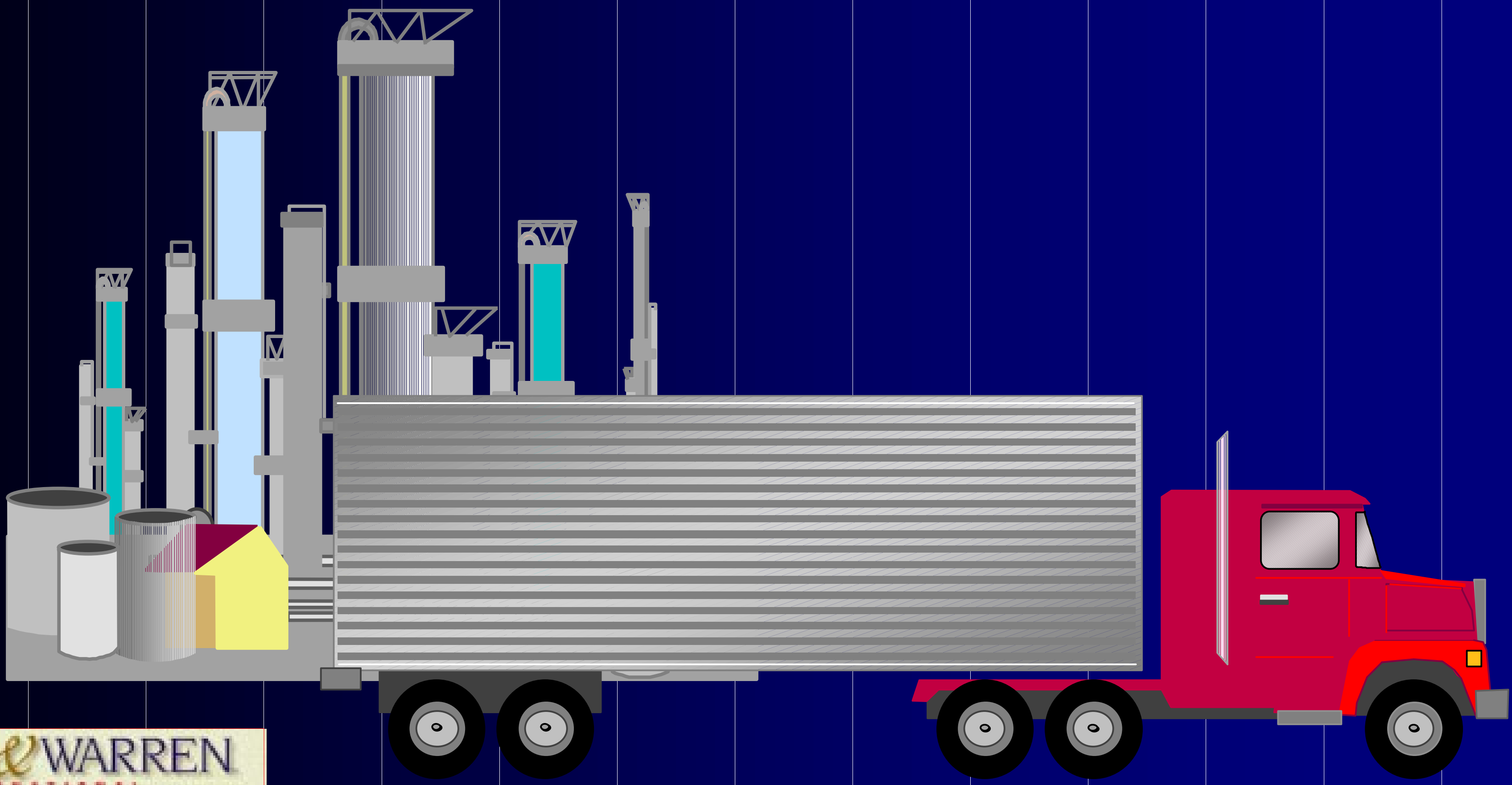
Sampling

- Measure total outgoing variation as sent to the customer



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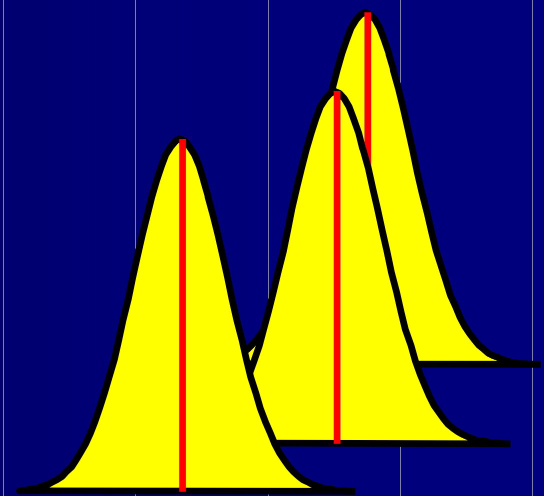
Total Outgoing Variation

- Variation inherent to the process
- Variation from sources such as:
  - differences from lot-to-lot,
  - tool-to-tool,
  - line-to-line,
  - shift-to-shift,
  - setup-to-setup,
  - day-to-day,
  - and throughout maintenance cycles.



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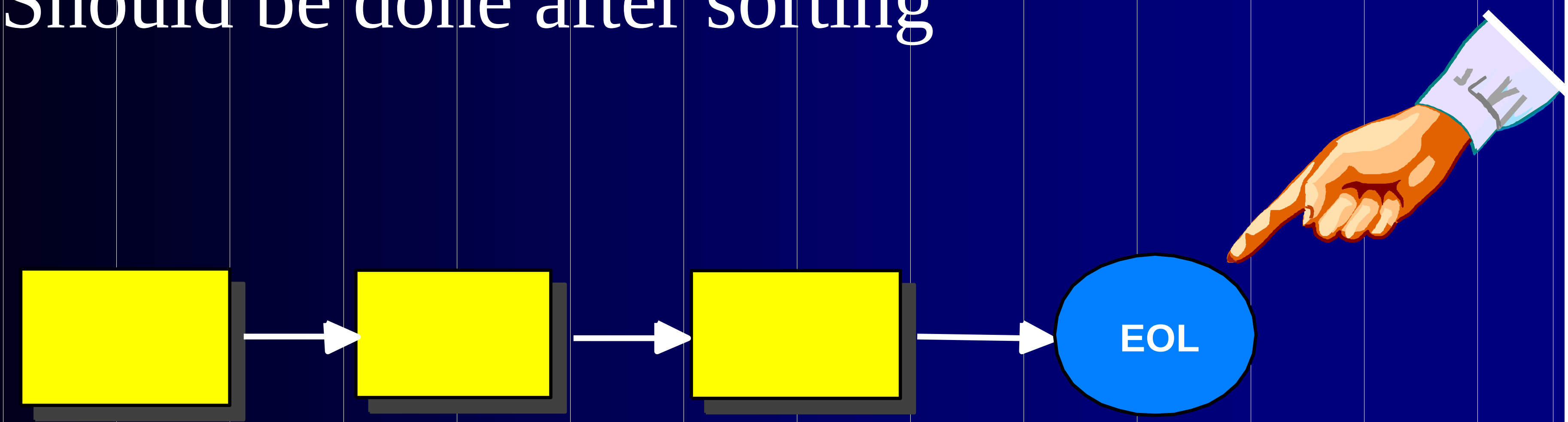
Sampling

- Generally done at end-of-line
- May be done upstream if characteristic formation is complete and will not change
- Should be done after sorting



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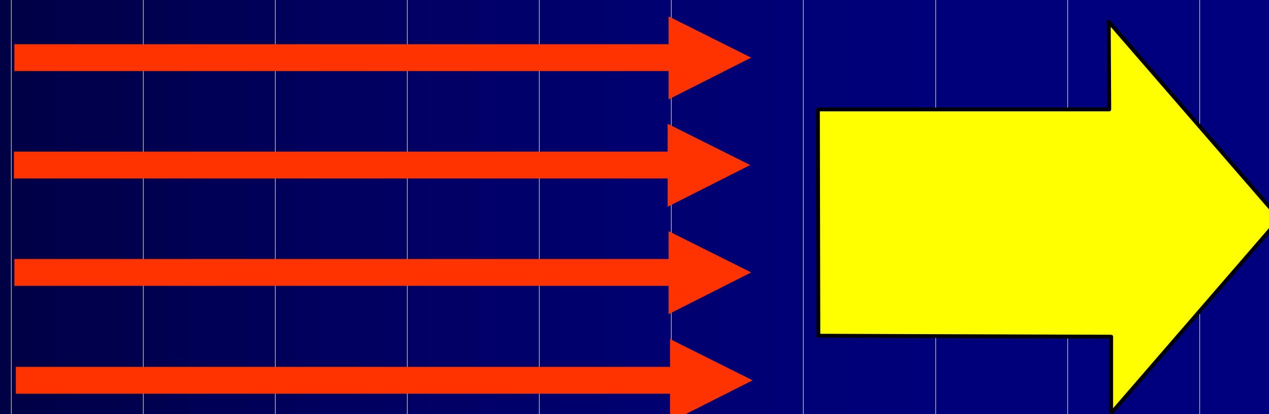
Stratification

- Used for process diagnosis
- Stratifications may include:
  - Lines
  - Tools
  - Stations
  - Cavities
  - or Other



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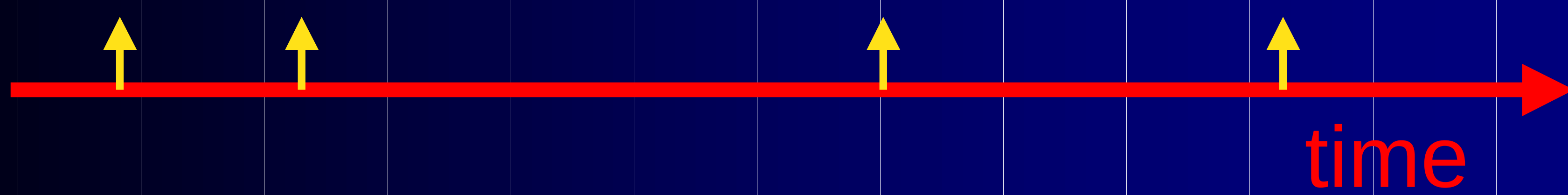
Sample Frequency

- Samples taken periodically within defined time periods



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Sampling Amount

- Long periods are preferred
- Minimum one month, preferably, three months worth of data
- 1,000 is a desired minimum
- 10,000 or more may provide better analysis

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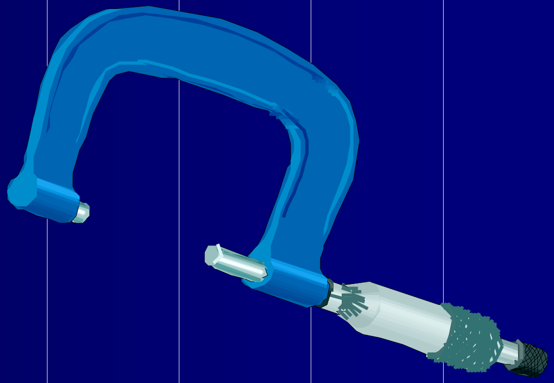
Measurement System Analysis

- Measurement system analysis should be conducted prior to data collection



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Process Performance Measures

- Ppm
- Ppk
- Pp
- Pp(process stream)
- Cp(potential)

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Ppm

- Assessing overall performance

$$P_{pm} = \frac{USL - LSL}{6\sqrt{\frac{\sum (X-T)^2}{n-1}}} = \frac{USL - LSL}{6\sqrt{s^2 + \frac{n}{n-1}(\bar{X}-T)^2}}$$

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Ppm will improve as:

- Process brought into better control
- Differences in tooling, setup, operators, machines, and material are reduced
- Process brought on target
- Inherent process variation reduced

Ppk

- Assessing overall performance without targets

$$P_{pk} = \frac{\min(USL - \bar{X}, \bar{X} - LSL)}{3s}$$

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Pp

- Assessing performance as if process was on target

$$Pp = \frac{(USL - LSL)}{6s}$$

% Off-Target

- A further diagnostic measure

$$\%\ \textit{Off-Target} = \frac{|\bar{X} - T|}{USL - LSL} \times 100\%$$

Pp (process stream)

- Assessing performance without process stream differences

$$Pp_{\text{(process stream)}} = \frac{(USL - LSL)}{6\, s_{\text{within stream}}}$$

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% Process Stream Difference

- A further diagnostic measure

% Process Stream Difference =

$$\frac{\left| \bar{X}_{max\ stream} - \bar{X}_{min\ stream} \right|}{USL - LSL} \times 100\%$$

Cp (potential)

- Assessing Potential Performance

$$C_{p(potential)} = \frac{(USL - LSL)}{6\,\hat{\sigma}_{potential}}$$

Potential Standard Deviation

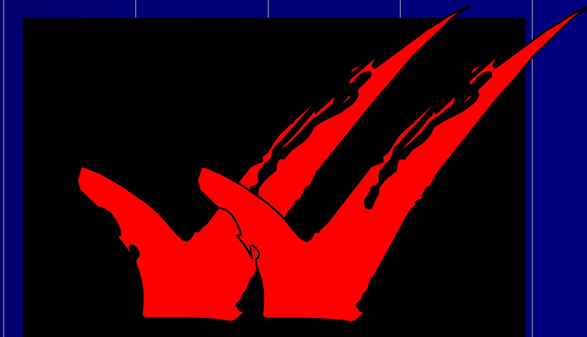
- Short-term capability studies
- Estimated using average or median dispersion statistics

$$\hat{\sigma}_{\text{potential}}$$

A further check

- Observed Nonconforming Rates

$$\textit{Nonconforming Proportion (ppm)} = \frac{\textit{1,000,000 x Total Nonconforming}}{\textit{Total Items}}$$



Attributes Data

- Similar sampling may be done for attributes
- Nonconforming rate used to evaluate attribute performance

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Stacked Bar Charts

- The following Relation holds:

$$P_{pm} \leq P_{p} \leq P_{p(\text{process stream})} \leq C_{p(\text{potential})}$$

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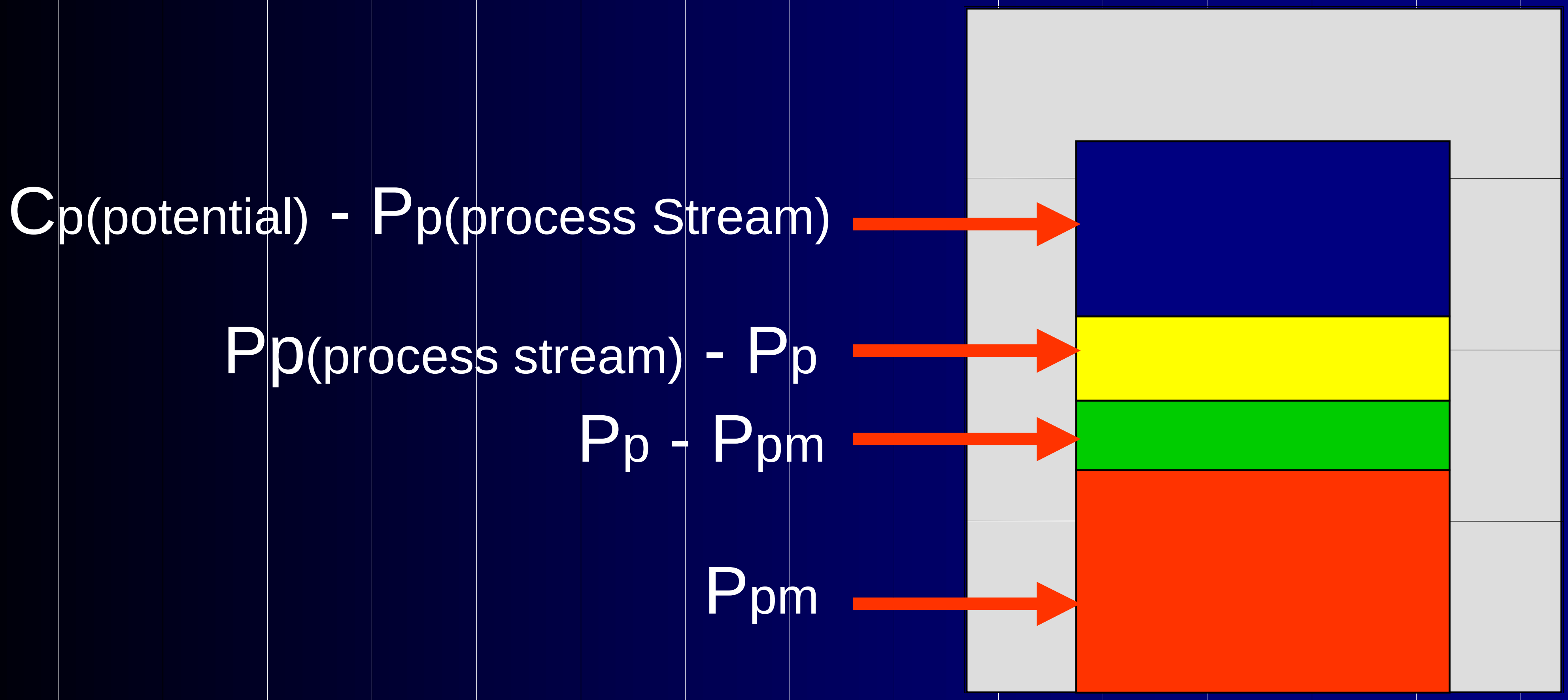
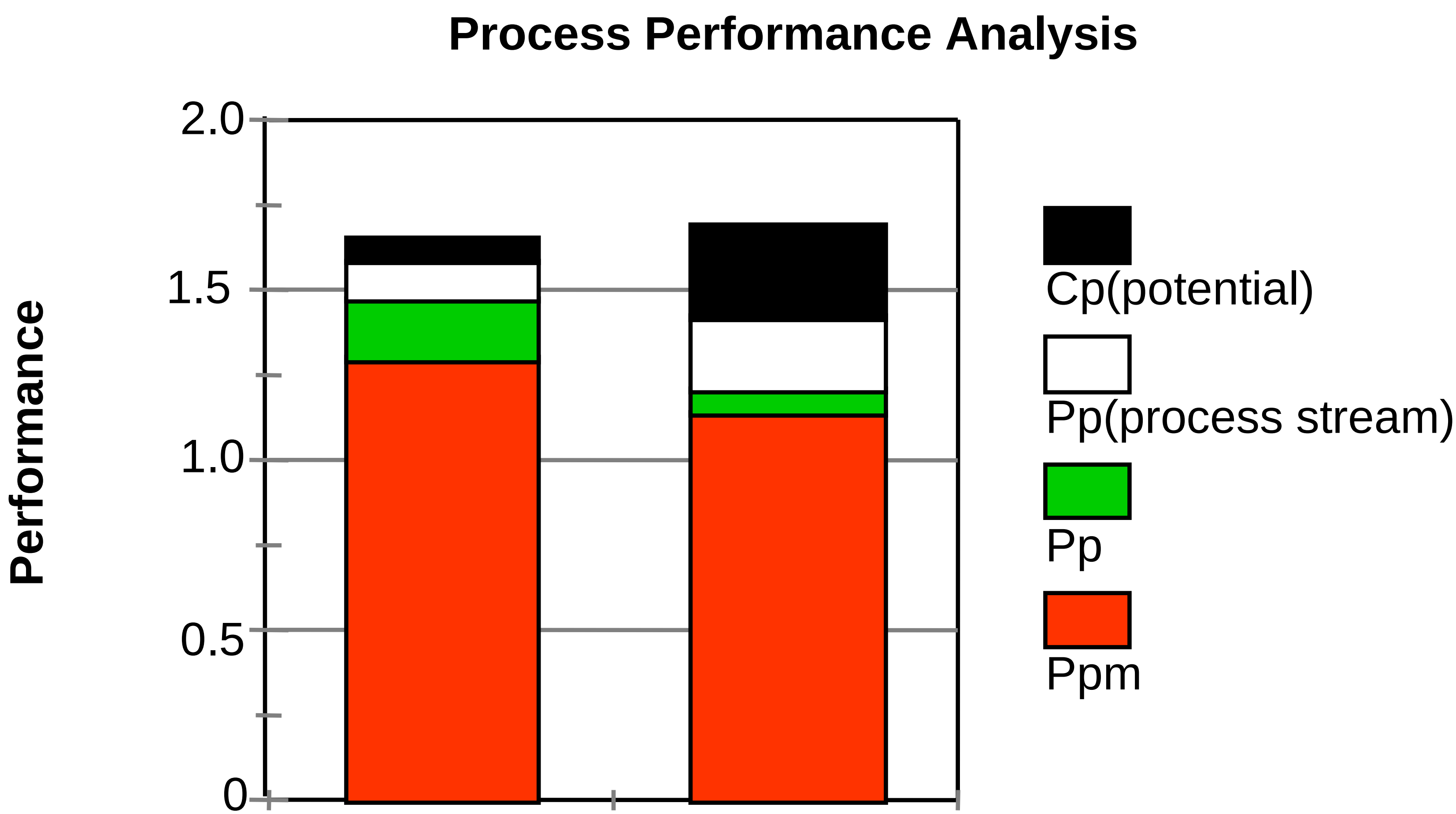
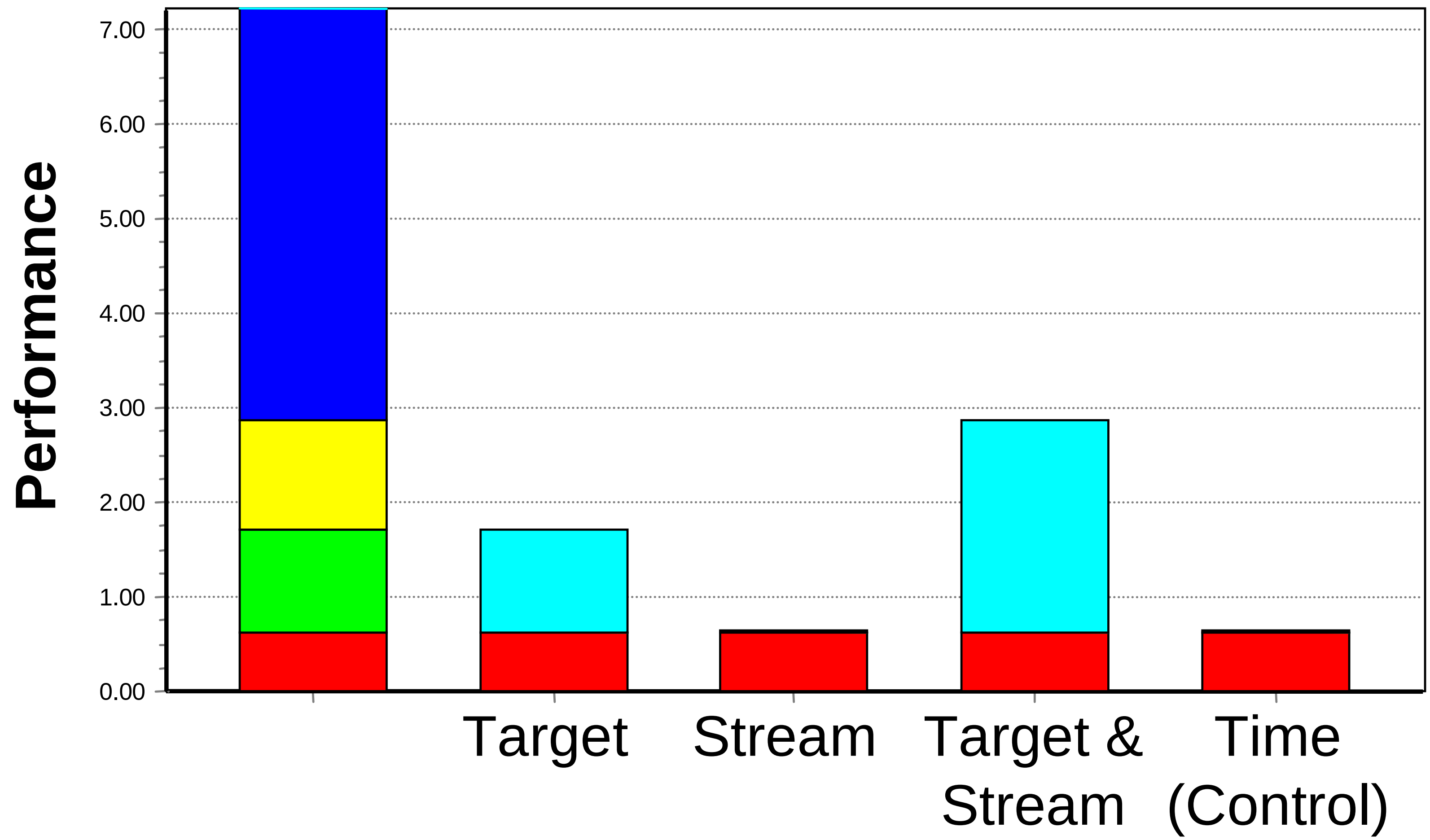
Stacked Bar Charts



Stacked Bar Charts



Cannot Compare Areas of the Stacked Components



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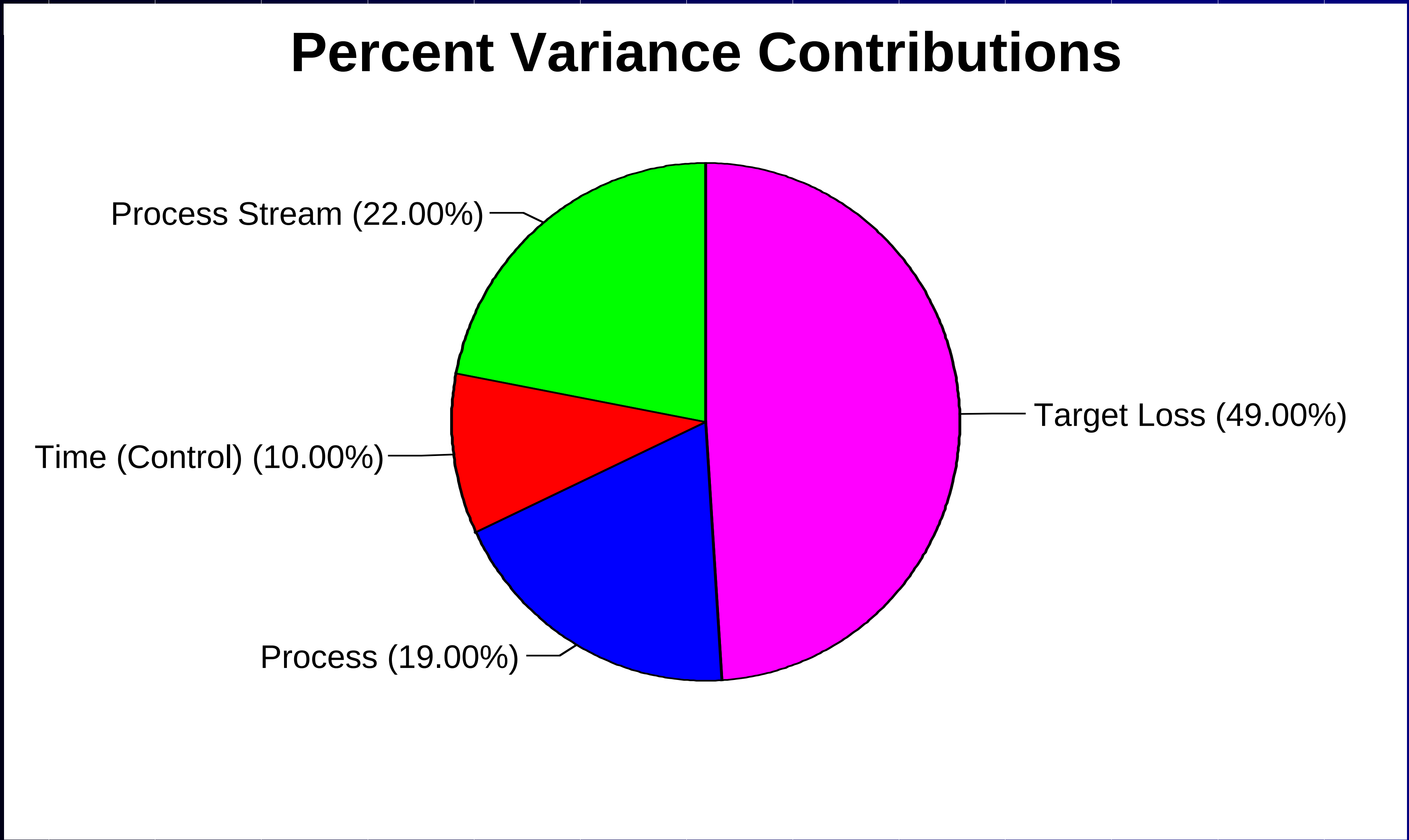
Variance Components

- Total variance about target, τ^2, can be decomposed
- May be done with simple formulas

$$\tau^2 = \sigma^2_{\text{potential}} + \sigma^2_{\text{off-target}} + \sigma^2_{\text{process stream}} + \sigma^2_{\text{time}}$$

Variance Components



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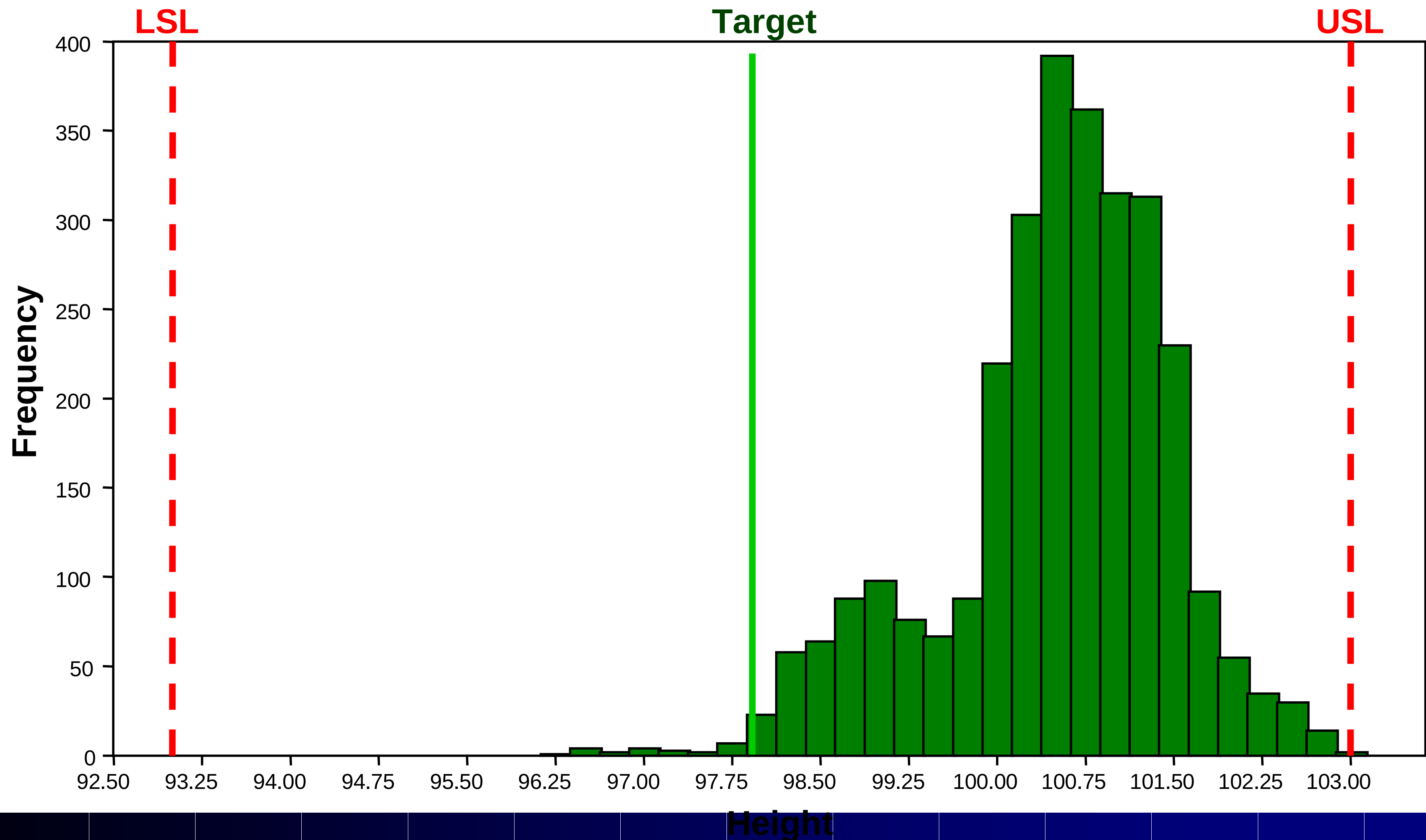
Case Study
Aluminum Lids - Height

- Aluminum Lids are produced on a Press with 22 Stations
- Each day, Lids from each Station are sampled and Lid Height measured
- Each sample contains a single Lid from each station
- Data collected over Three-month period
- Specifications are 98 ± 5

Histogram of Combined Data



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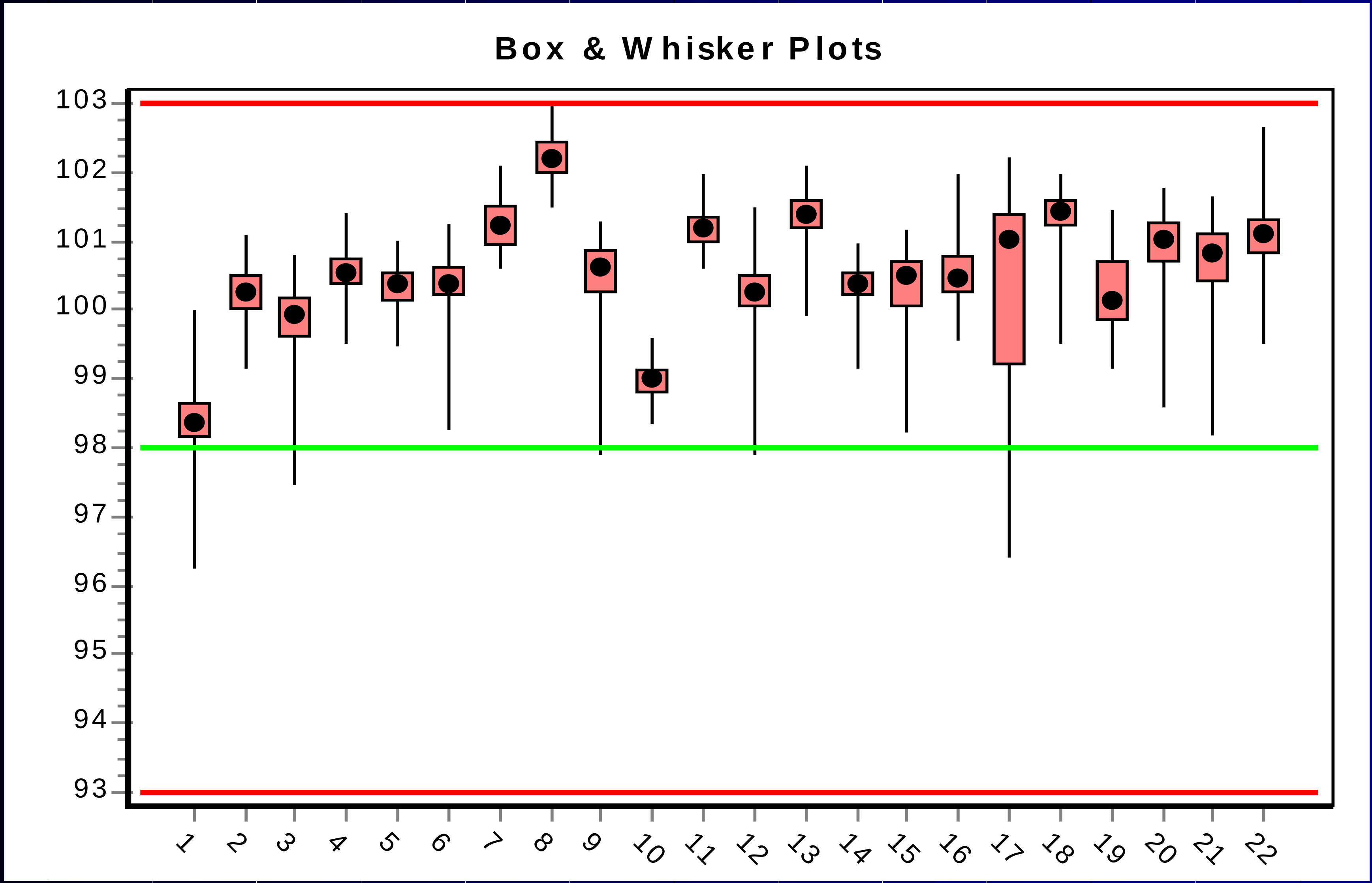
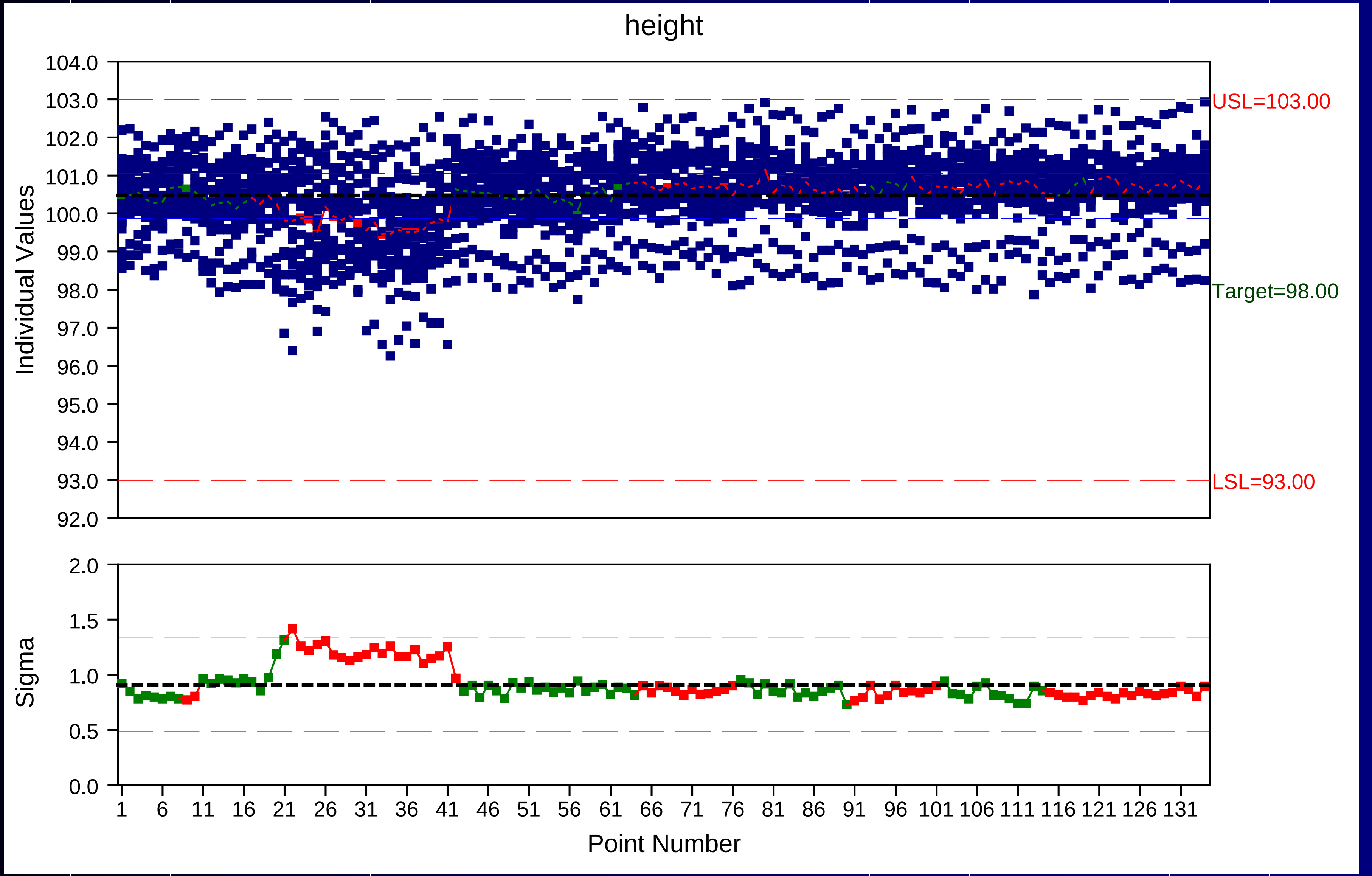
Box Plot of Each Station



Run Chart of Combined Data



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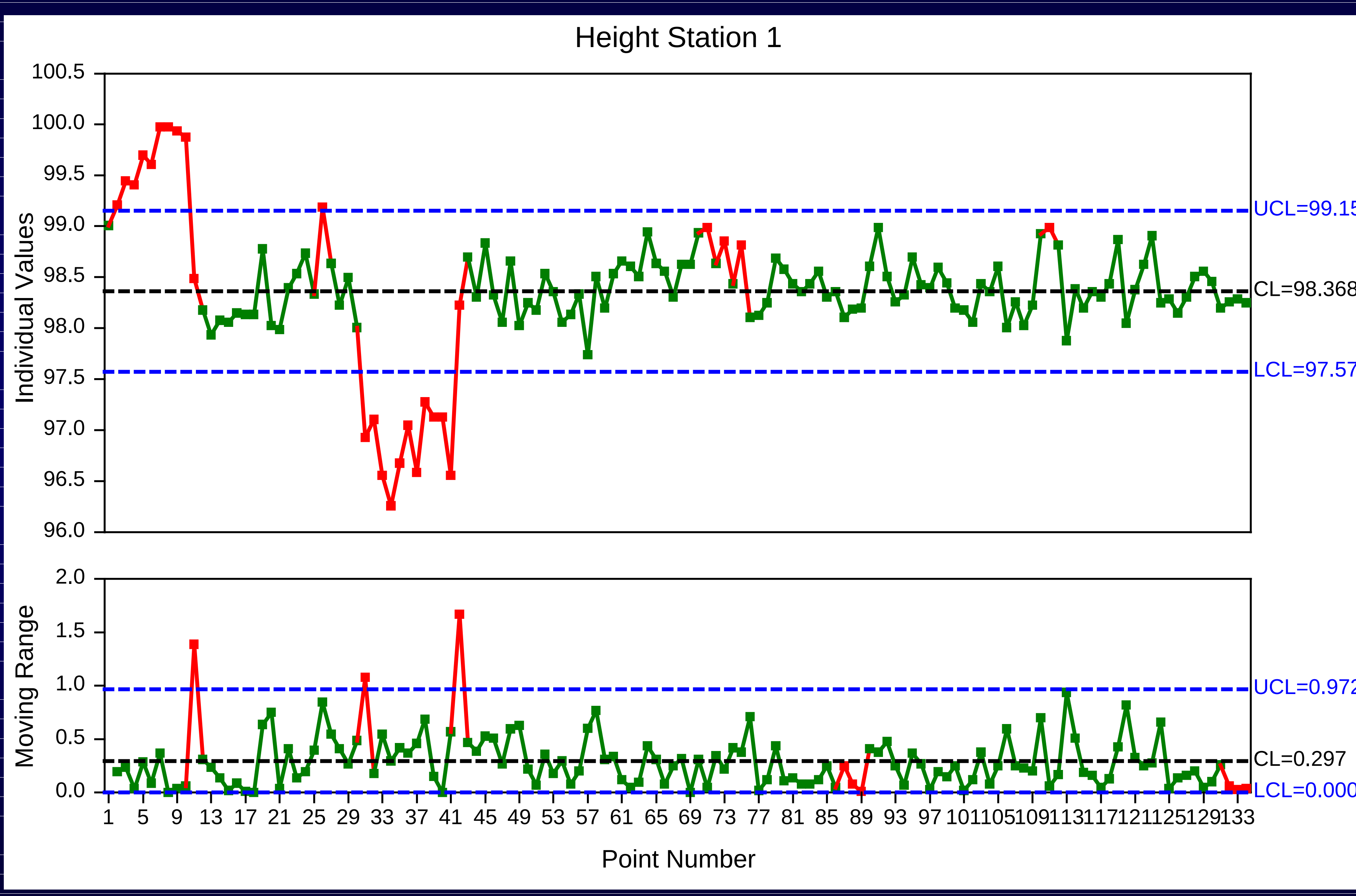
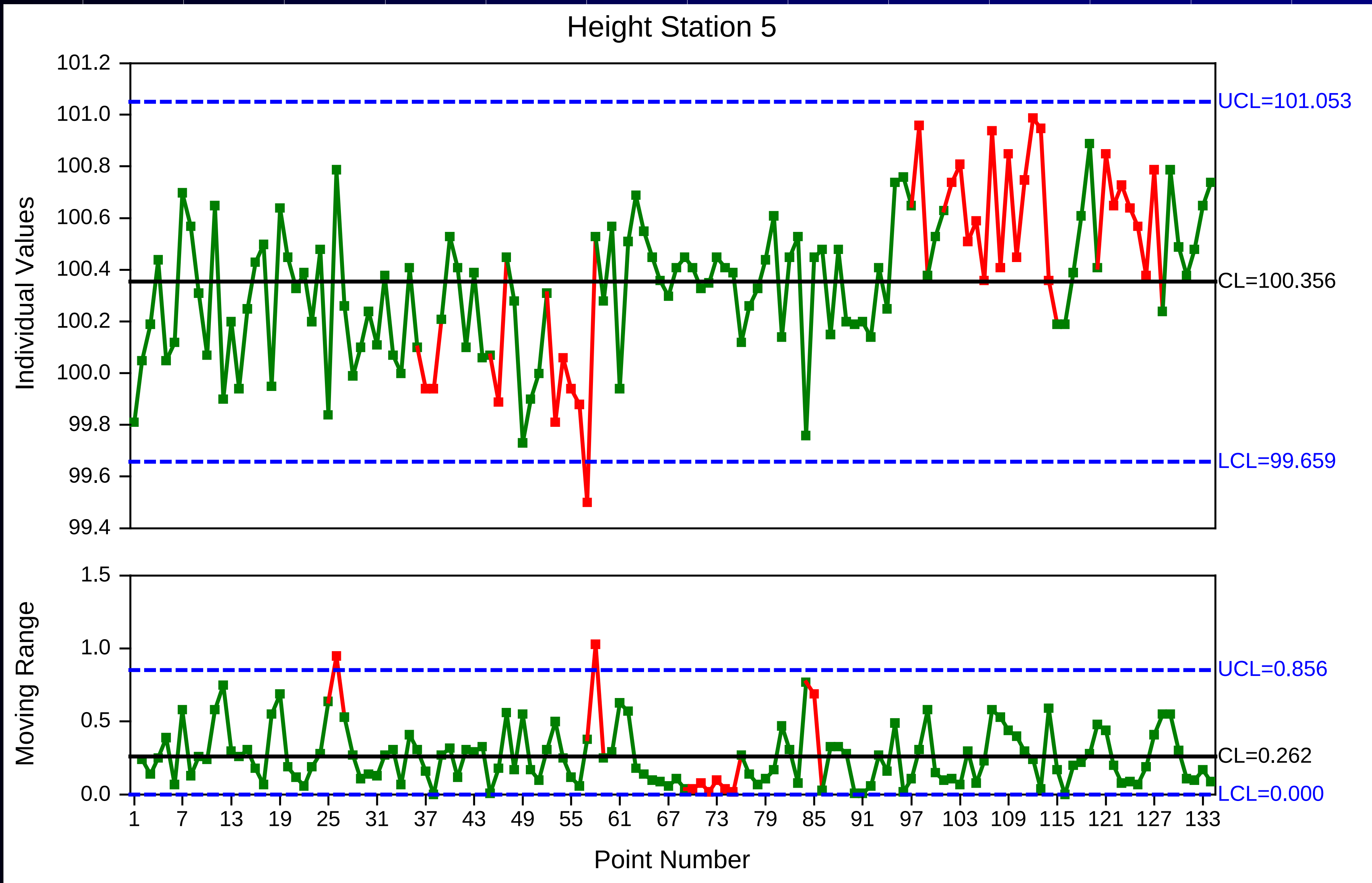
Control Chart from Station #1



Control Chart from Station #5



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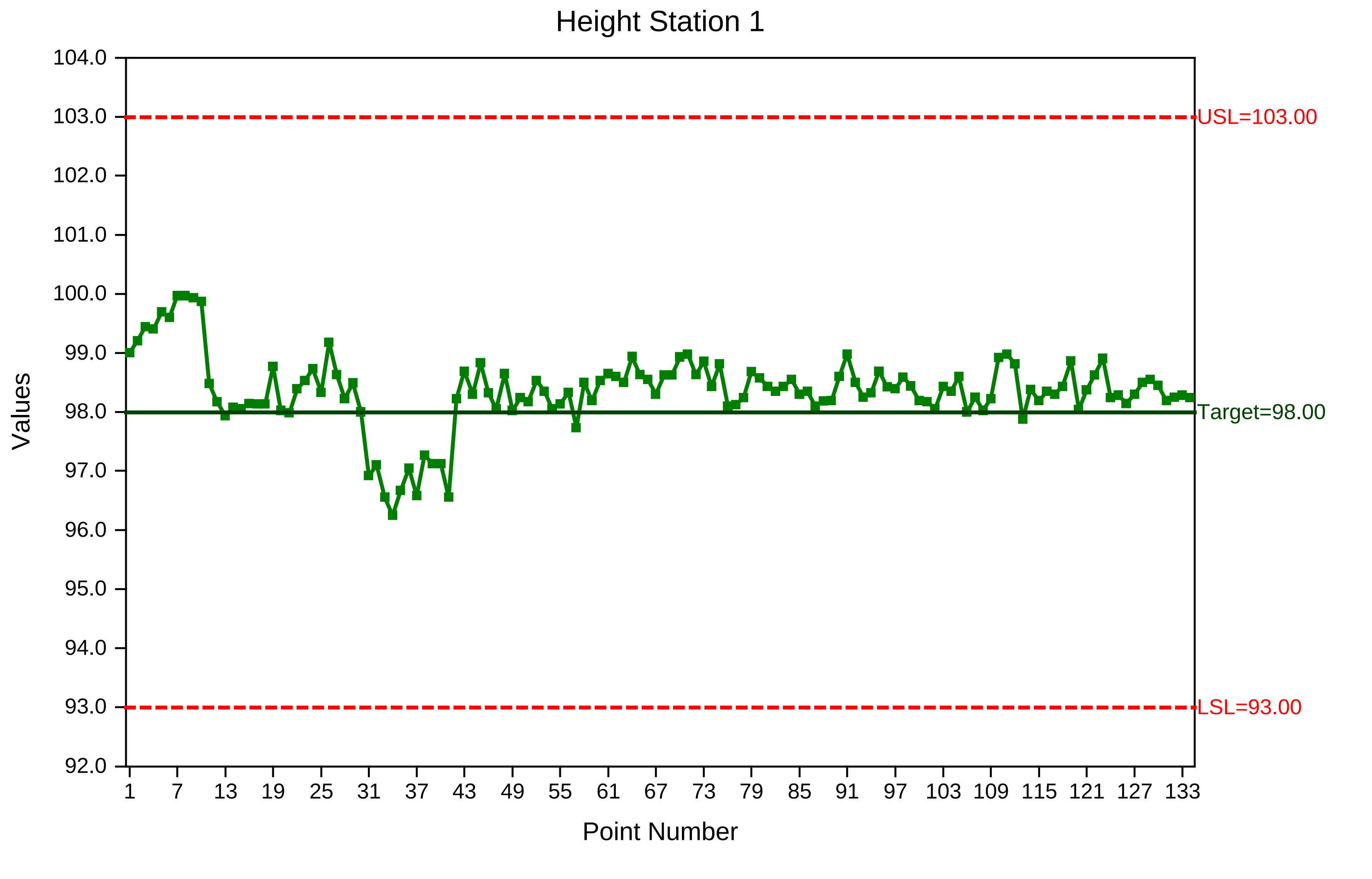
Run Chart Station #1 with Specs



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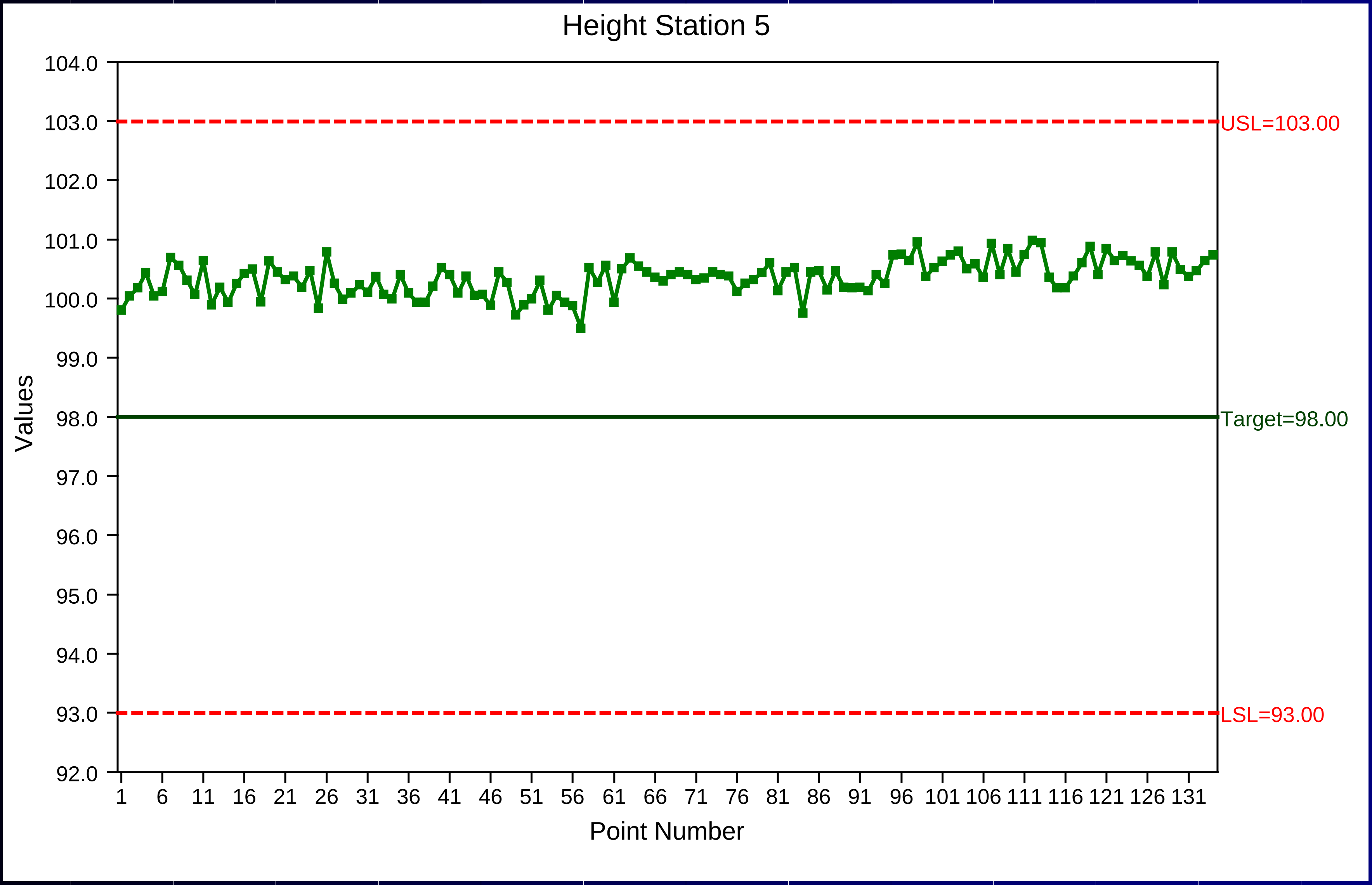
Run Chart Station #5 with Specs



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Descriptive Statistics

Station	n	mean	s	s(MMR)
1	134	98.37	0.63	0.26
5	134	100.36	0.29	0.23
15	134	100.27	0.68	0.23
20	134	100.80	0.71	0.24
22	134	101.06	0.49	0.27

SQRT(MSW)
(Std Dev Within) = 0.58
AVG Std(MMR)
(Std Dev from Median MR) = 0.23

Descriptive Statistics

n	=	2948
Mean	=	100.48
Std. Dev	=	0.98
Low	=	96.26
Q1	=	100.06
Median	=	100.59
Q3	=	101.14
High	=	102.94

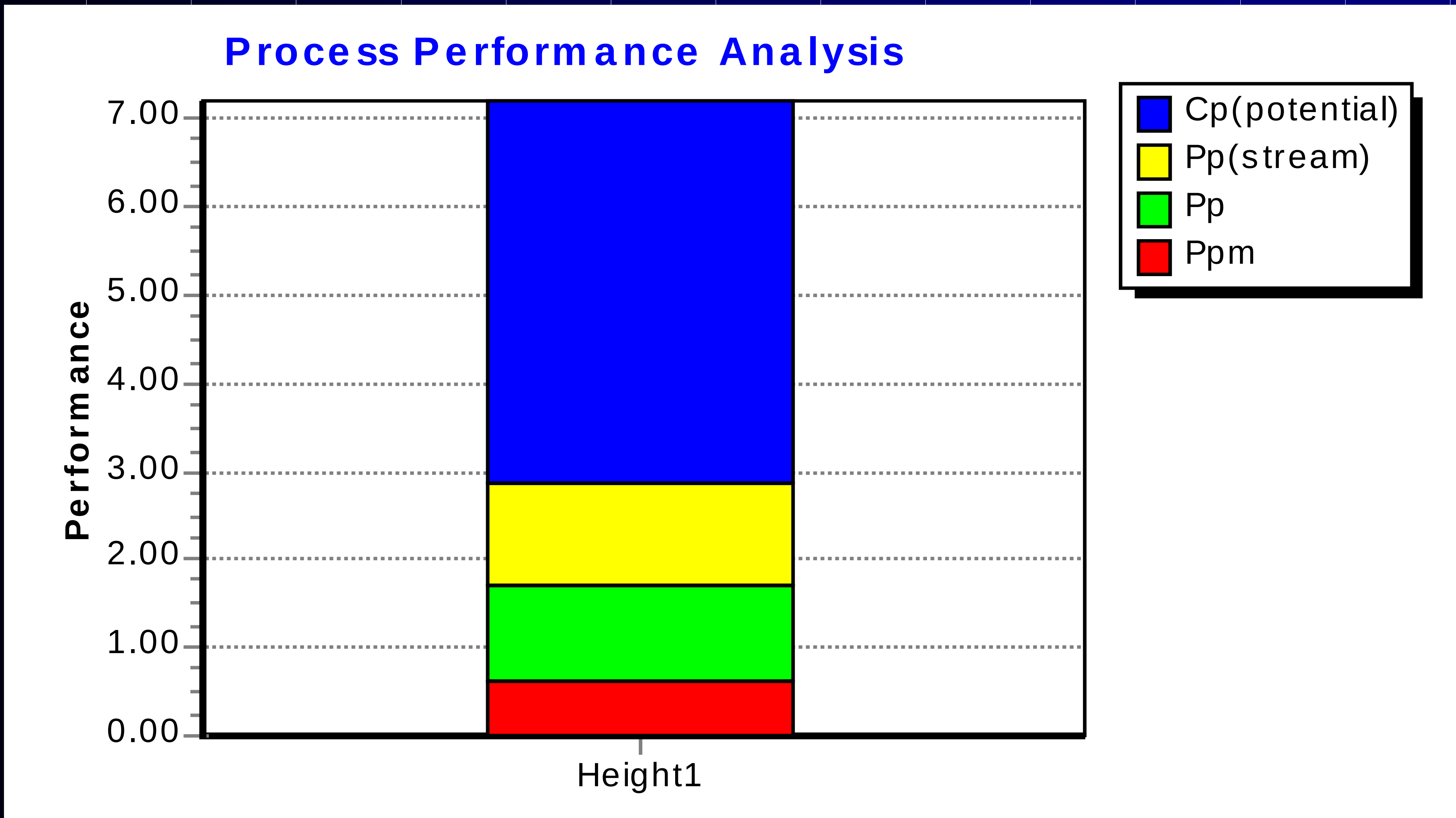
Performance Measures

```
%Off Target              =  24.82%
Max Station Mean         = 102.21
Min Station Mean         =  98.37
%Process Stream Loss =  38.42%

Ppk          = 0.858
Ppm          = 0.625
Pp           = 1.703
Pp(Stream)= 2.862
Cp(pot)      = 7.212

n = 2948
Total Out = 0   (0 ppm)
```

Process Performance Analysis



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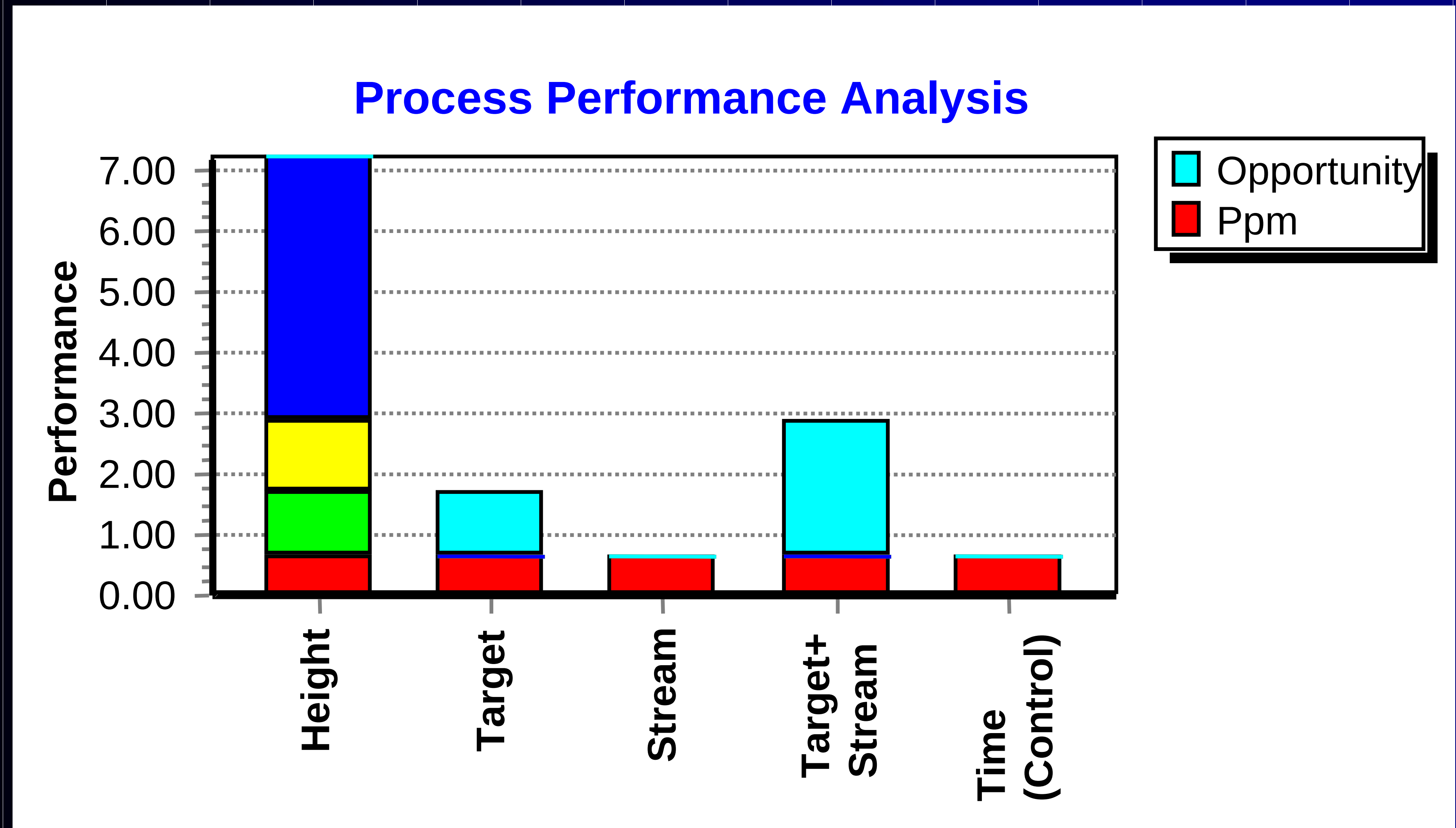
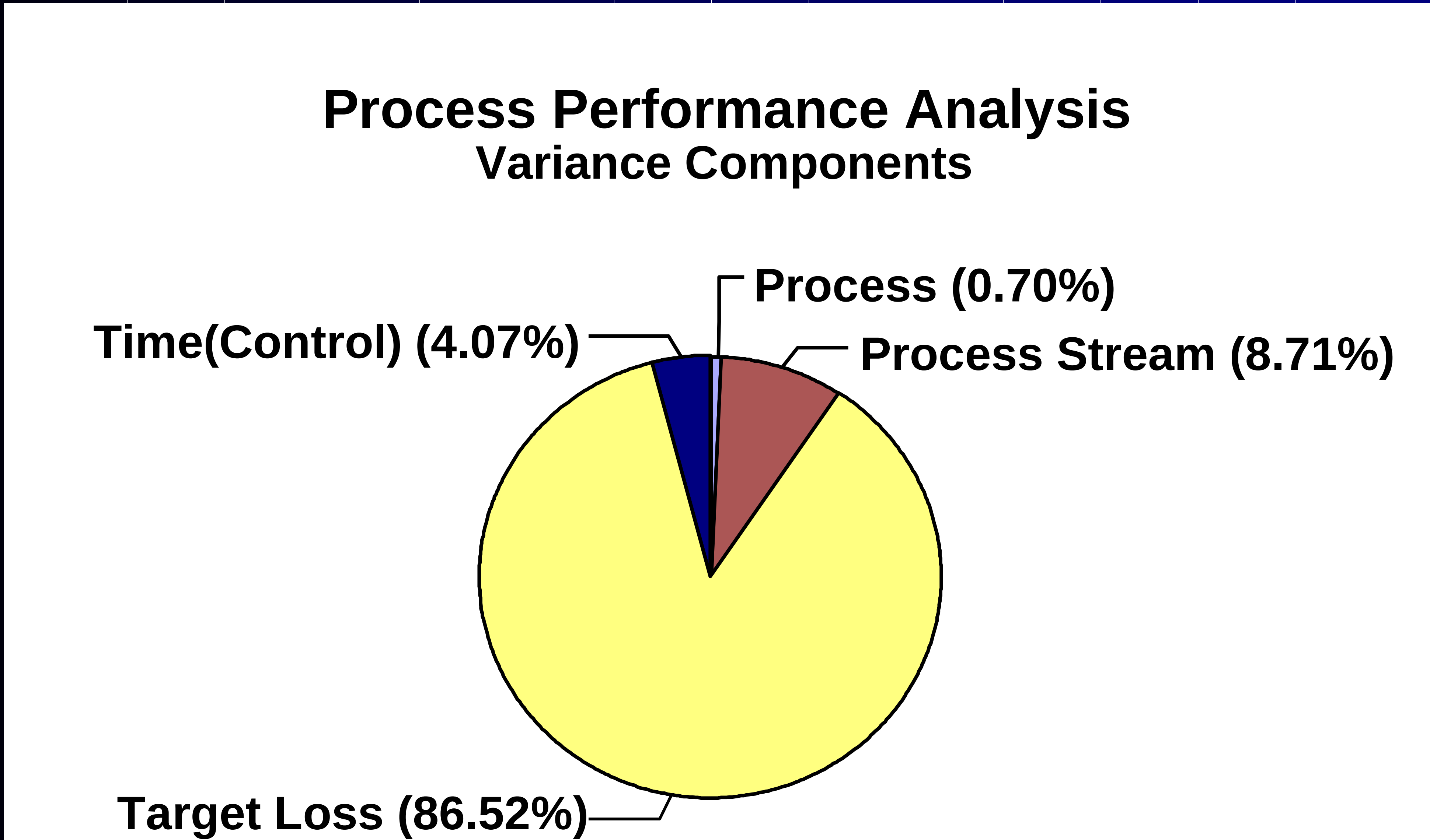


Variance Components



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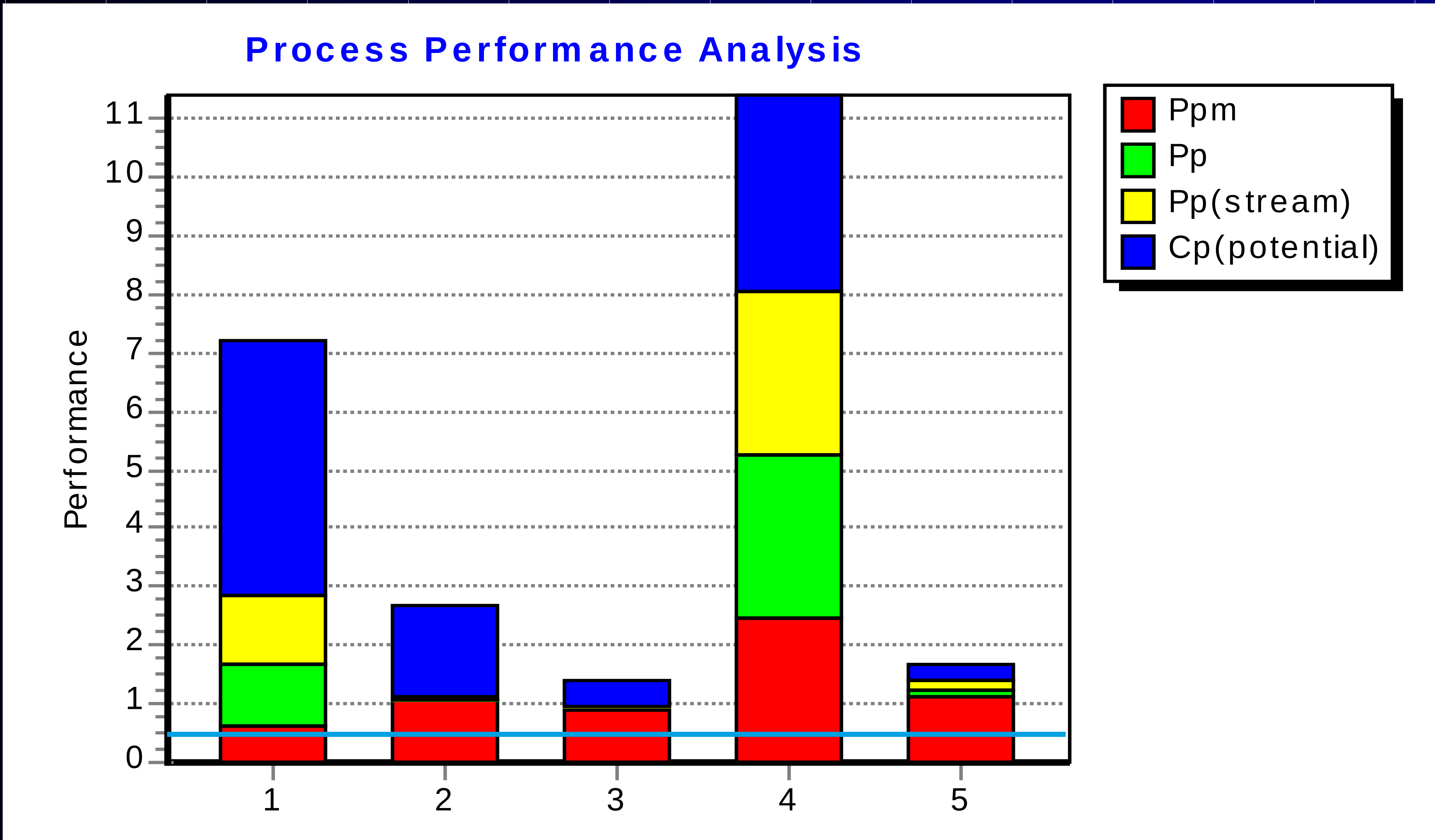
Conclusions for Example

- Biggest opportunity: getting the individual tools on target
- Improving through-time stability (control) will have minimal effect in this example

Summary Results of Selected Cases



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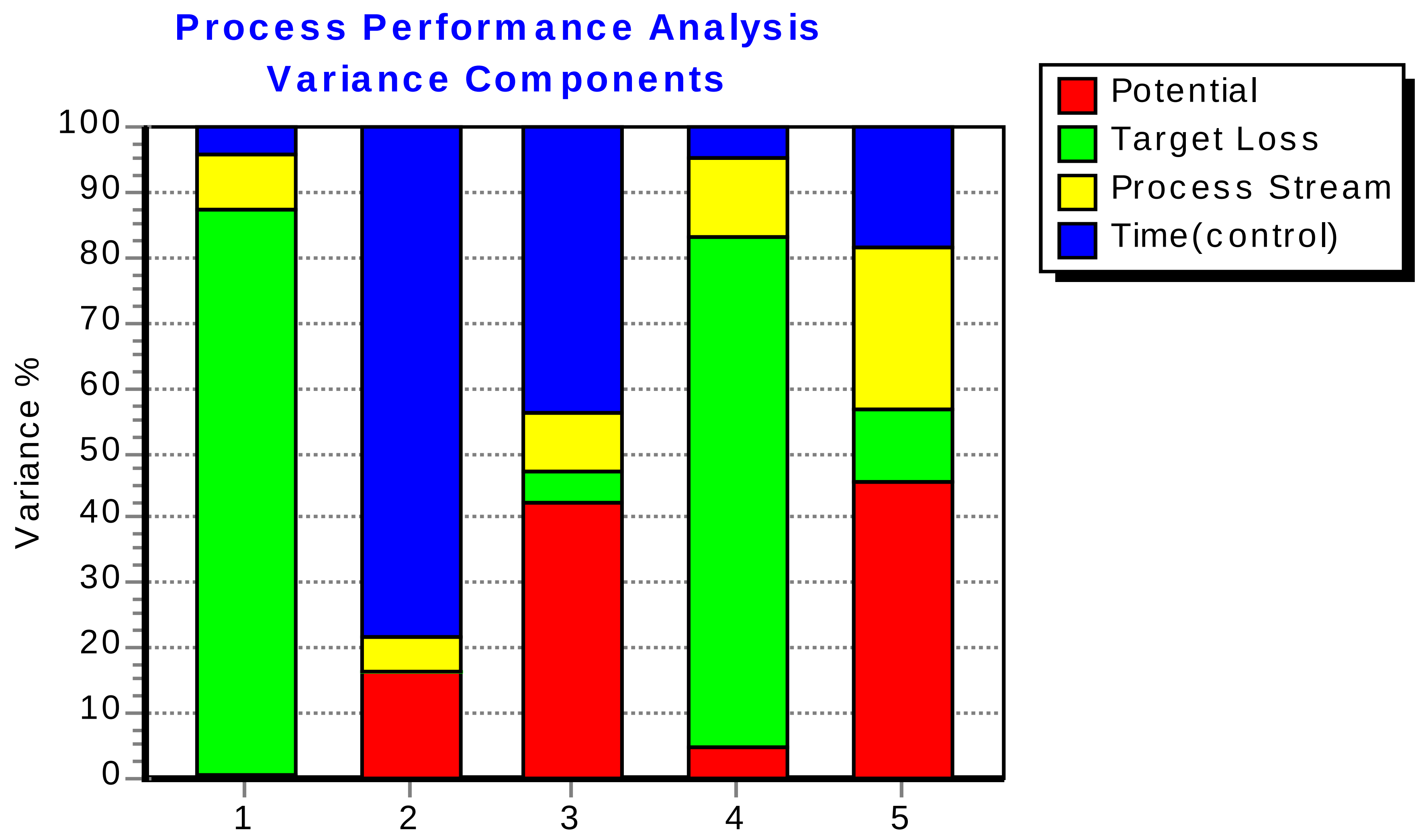

Conclusions

- Process Performance Analysis provides an effective means of describing performance of complex processes not in a state of control
- PPA is an effective means of showing effects of process control and improvement efforts
- PPA helps the practitioner determine how they are doing, what processes need work and which one do not
- PPA gives you another way of looking at your processes

The End

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