# Alarm Management with Operating Envelopes

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# Outline

- Introduction
- Role of Operator Alarms
- High Dimensional Operating Envelopes
- Visualizing Operating Envelopes in Alarm Rationalization
- Examples
- Dynamic Predictive Alerting for Abnormal Events
- Conclusions & Questions

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To see process manufacturing plants worldwide intelligently solve their most complex challenges, improve plant safety, increase batch consistency, reduce emissions and increase profitability.

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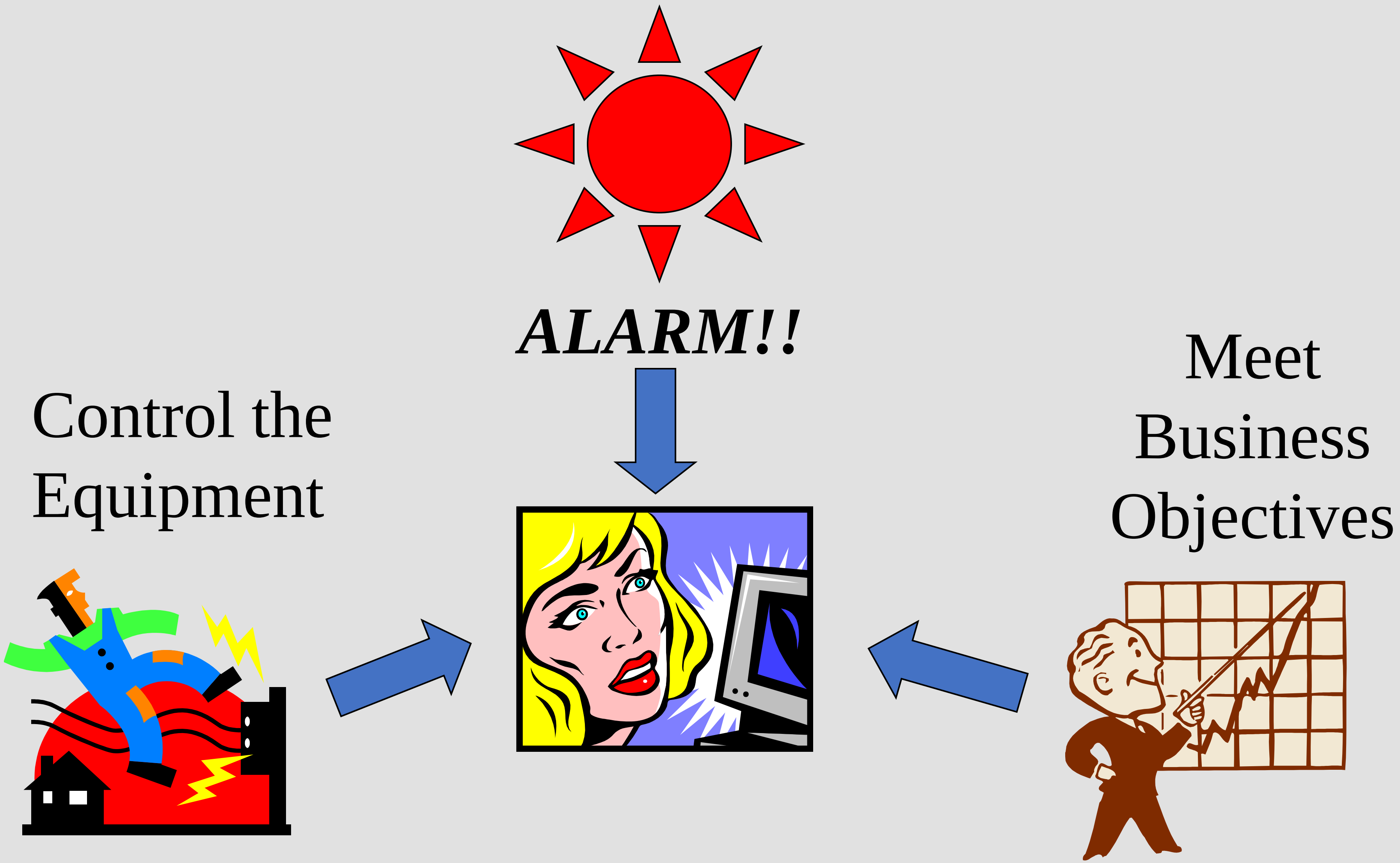
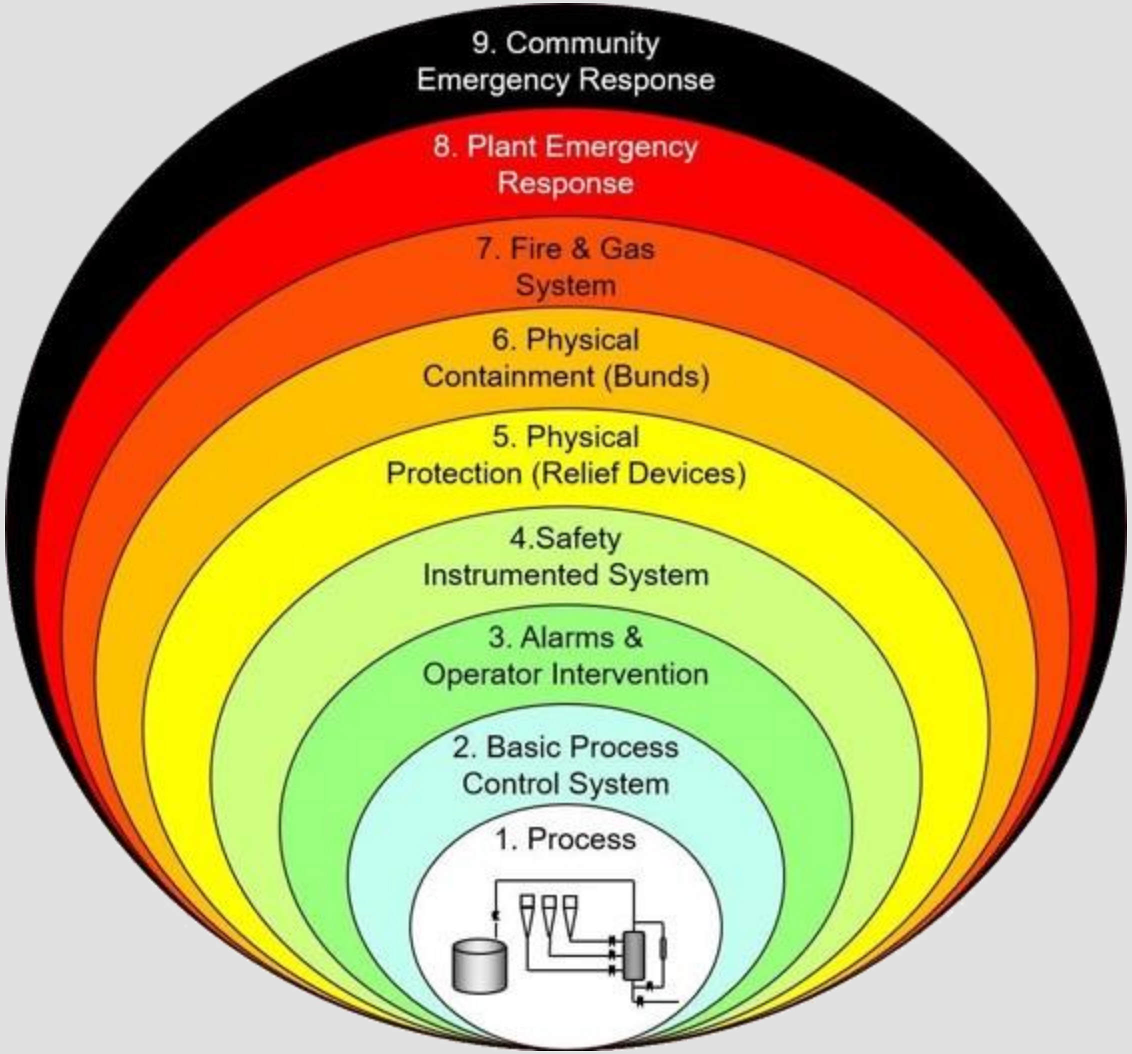
# The Role of the Operator



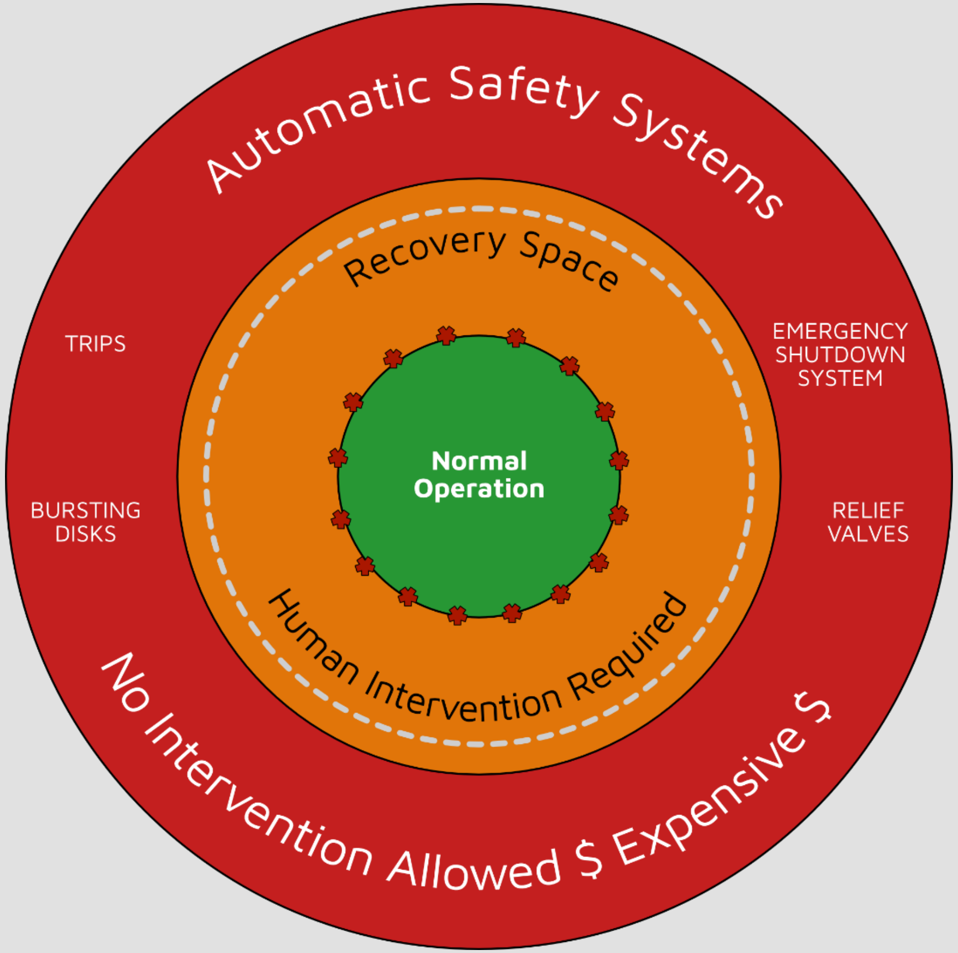
# Why have Operator Alarms – a LOPA view




- Alarms are requests from level 2 for the operator to intervene
- Levels 2 and 3 attempt to correct a problem that began in Level 1
- Levels 4 and above attempt to mitigate the consequences of not correcting the problem
- Cost penalty for failure rises very steeply with each level
- Level 3 is the highest level with human intelligence available - and has the highest PFOD

# Ideal Alarm Limits

- The Operator is the only chance for human intervention to prevent loss of production.
- Alarms are the prompts that something must be done to keep the process operating.
- Alarm limits at the boundary of normal operation give the best and earliest warning of developing situations.



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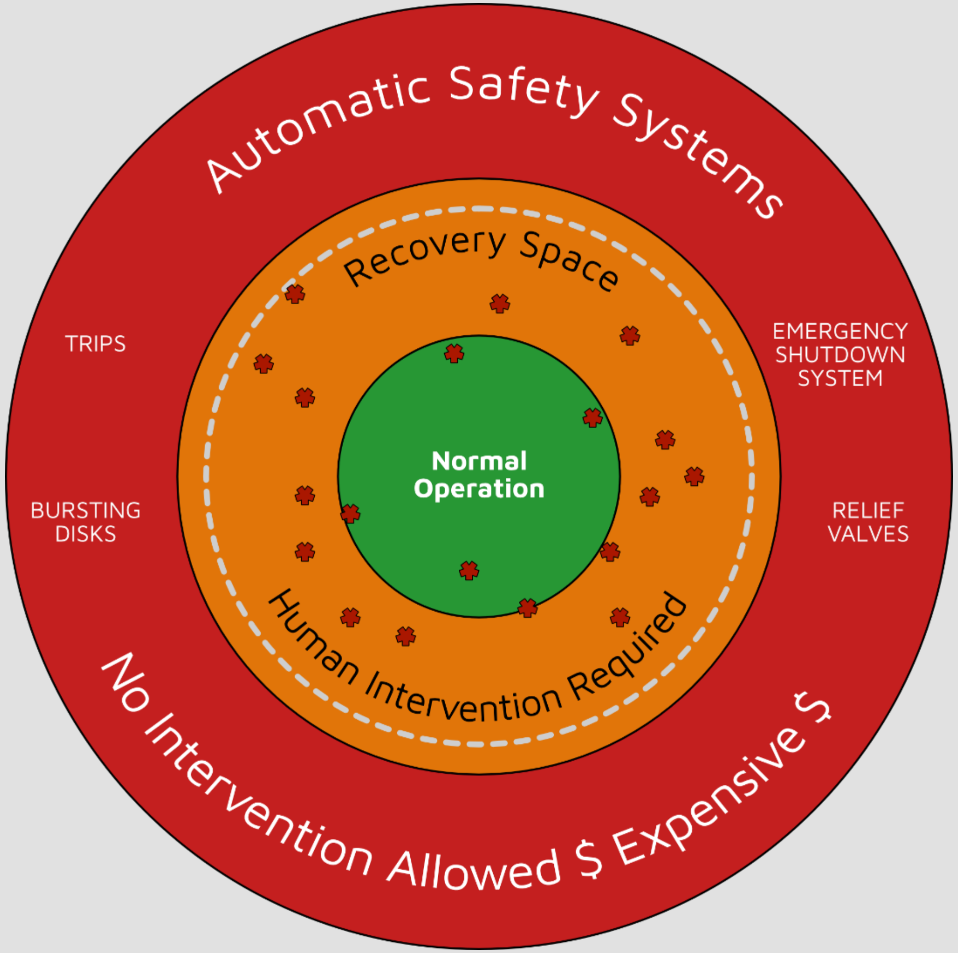
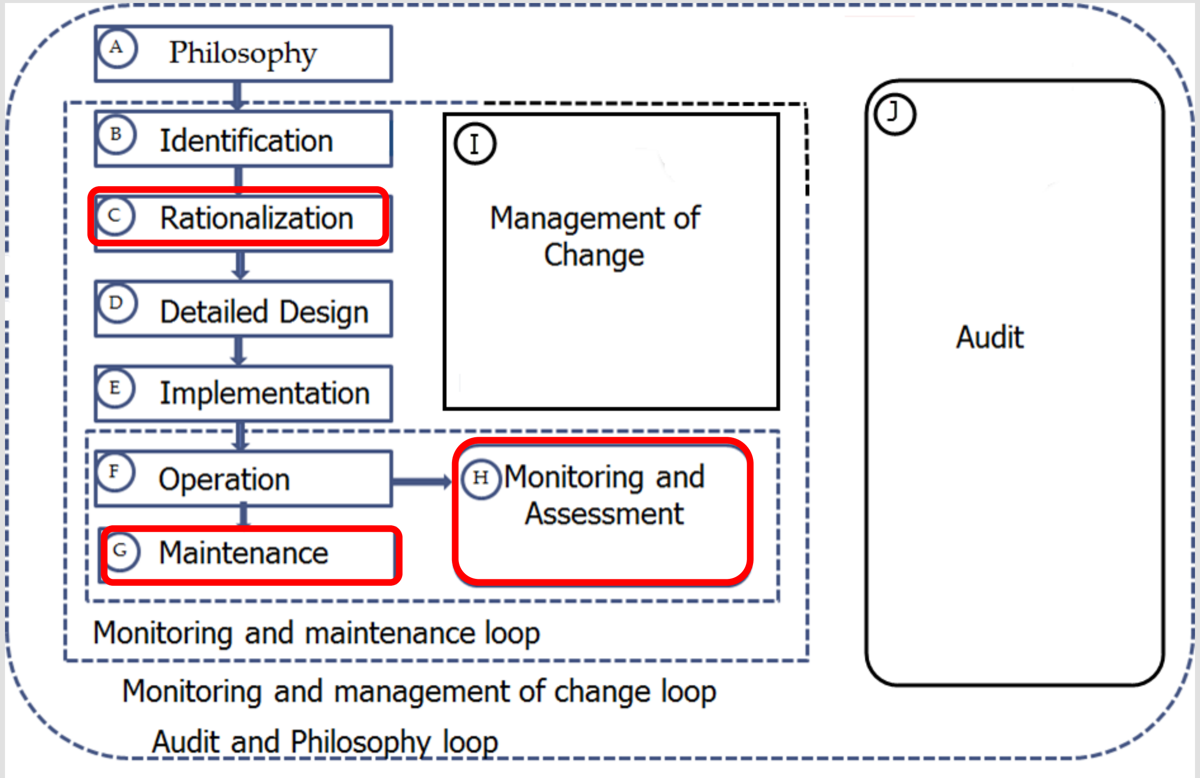
# Current Alarm Reality

- Shotgun pattern from complex alarm histories
- Alarms in the orange zone cause delay and require bigger corrections
- Alarm limits in the green space are false alarms requesting operator action when none is needed.
- Are “always-silent” alarms monitored?



# Process History in Alarm Management

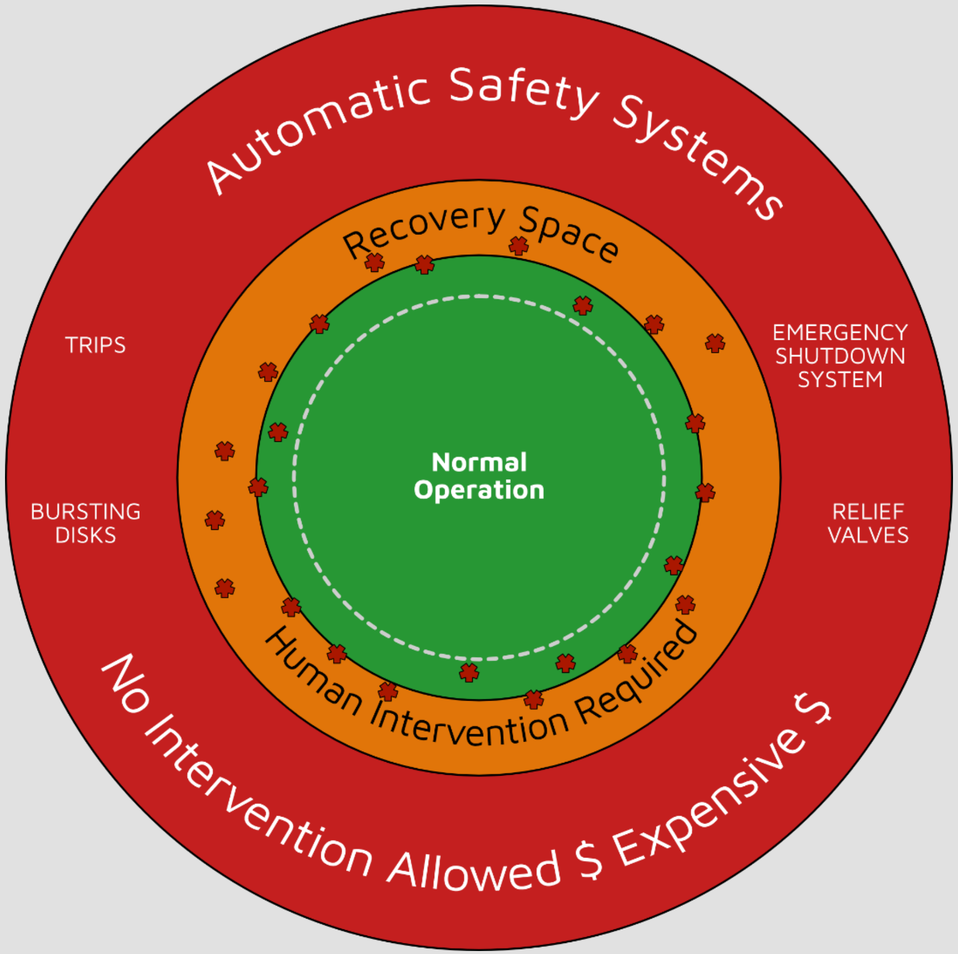



Process input is normally only used in the form of the event log: determining the performance of an alarm system by "Try-and-see"

With CVE, we can easily bring this into the Rationalization limit review step, and know before we try!

# Effect of Bad-Actor Reviews

- Traditional bad-actor reviews drive limits outwards
- Resulting alarm performance not known until weeks later
- Rationalization projects are repeated every 5 -7 years



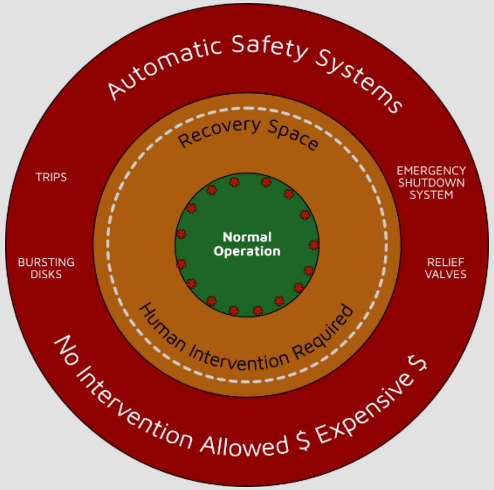
## How can we improve this with CVE?

- What if you could see the boundary of normal (and desired) operation?

- And put your alarm limits directly on them?

- You’d immediately improve and start getting the benefits of a good alarm system.

- Give Operations time to get used to trustworthy Alarms then add CPM to give them Alerts and and Event Prediction



# Geometric Process Control:

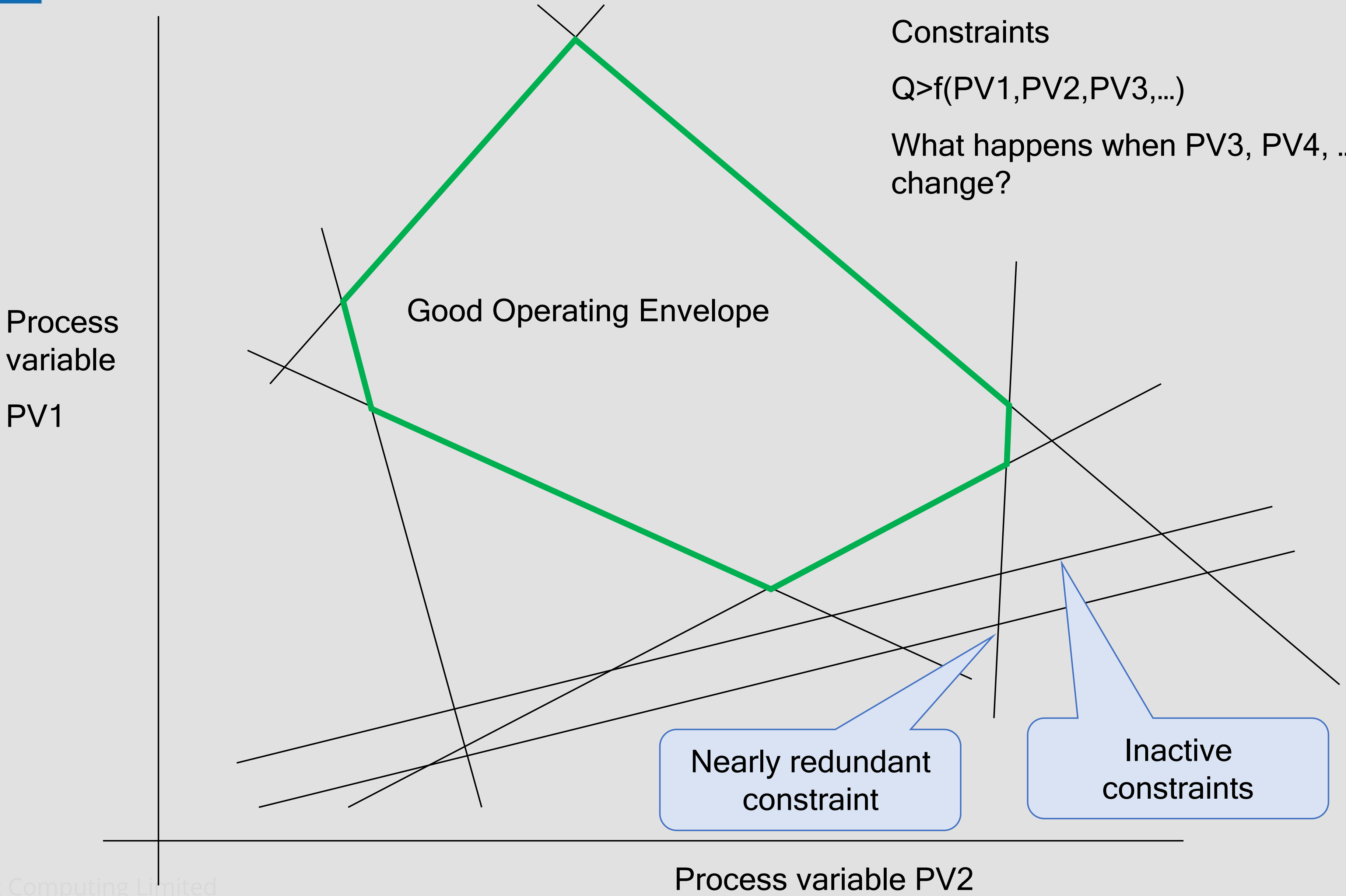
- Identifying Normal Operating Envelopes
- Positioning Alarm Limits on the Boundary
- Predicting Alarm Performance

# 2-D Schematic of Operating Envelope

Constraints

Q>f(PV1,PV2,PV3,…)

What happens when PV3, PV4, … change?



# 2-D Schematic of Operating Envelope

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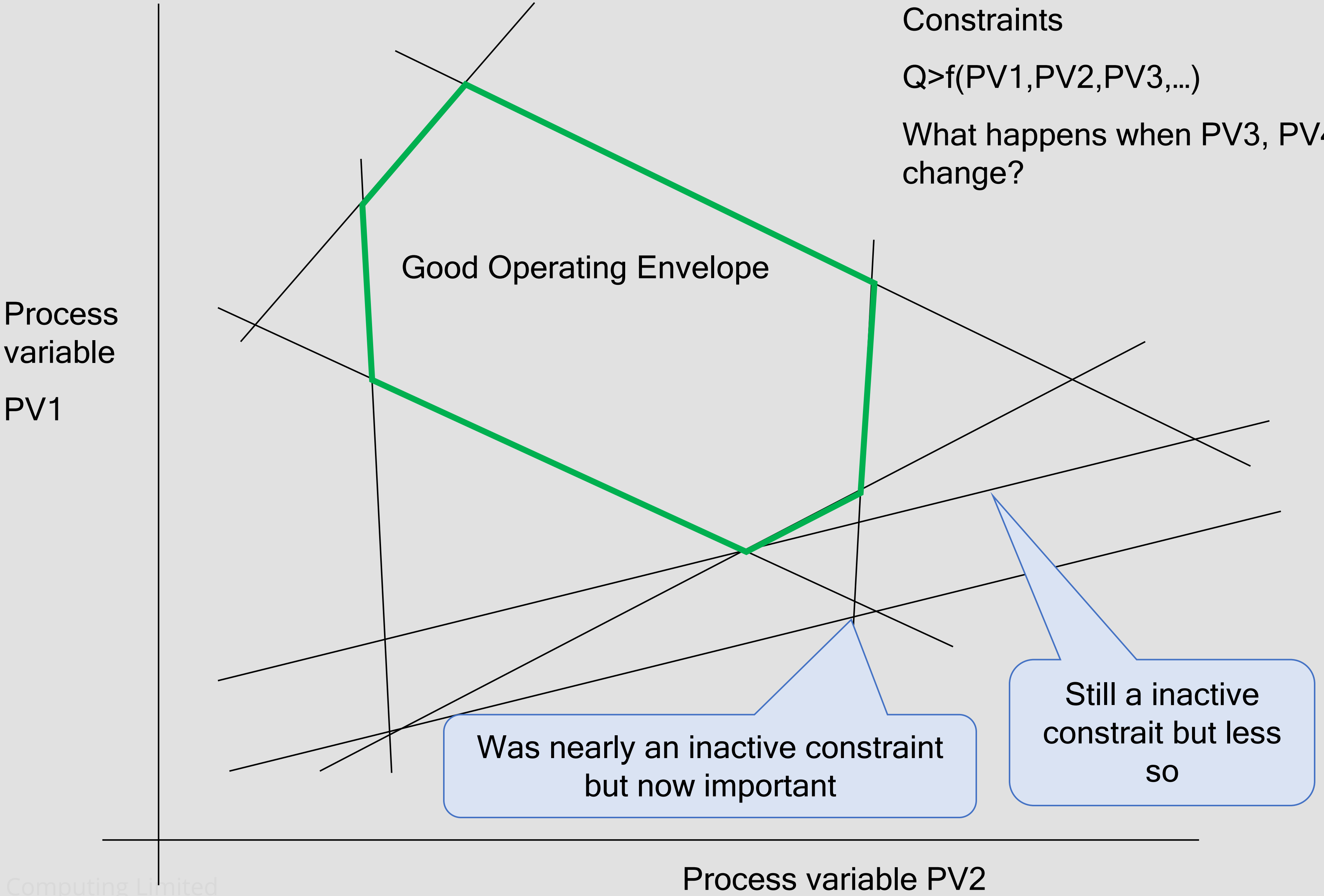
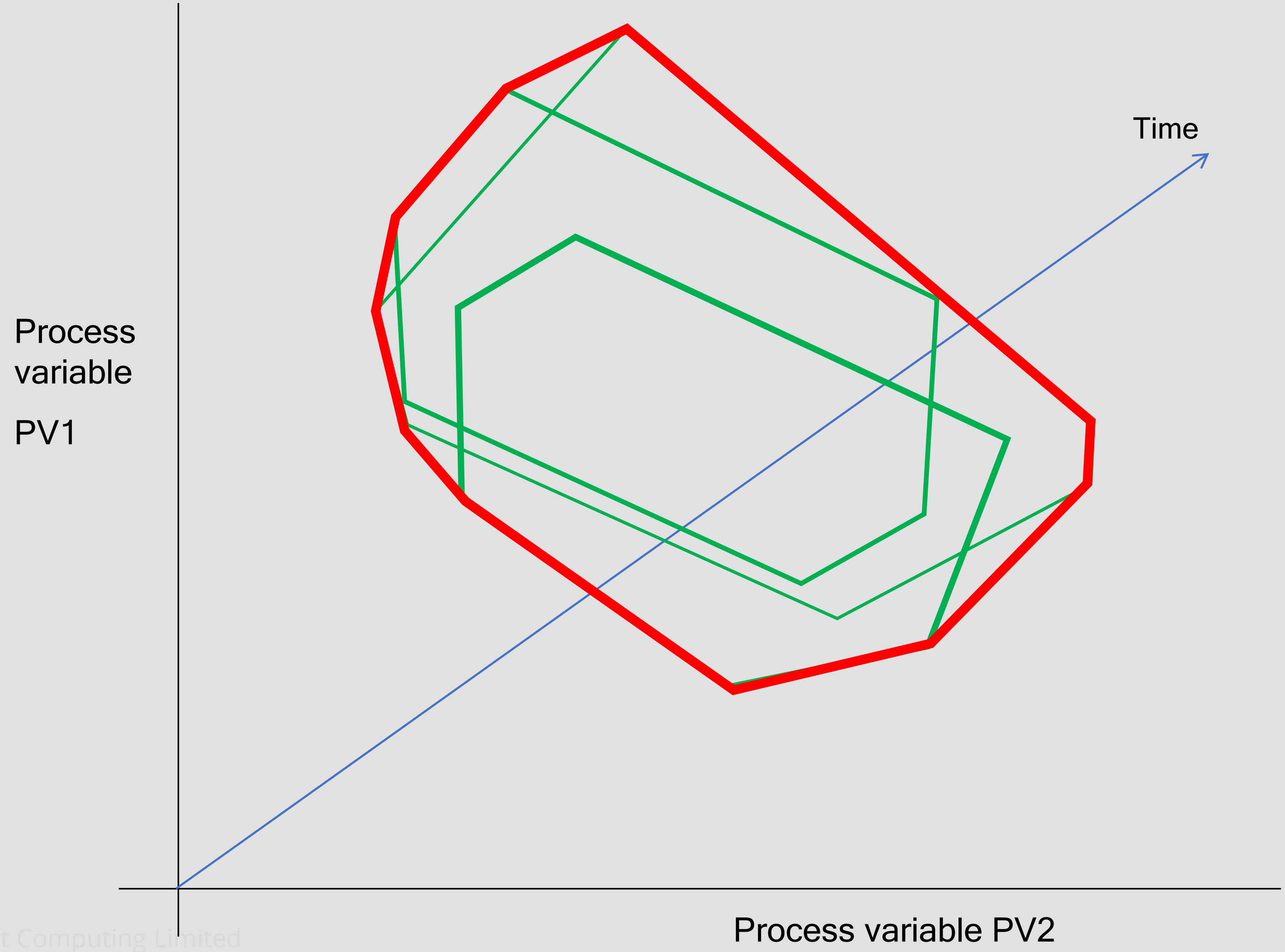
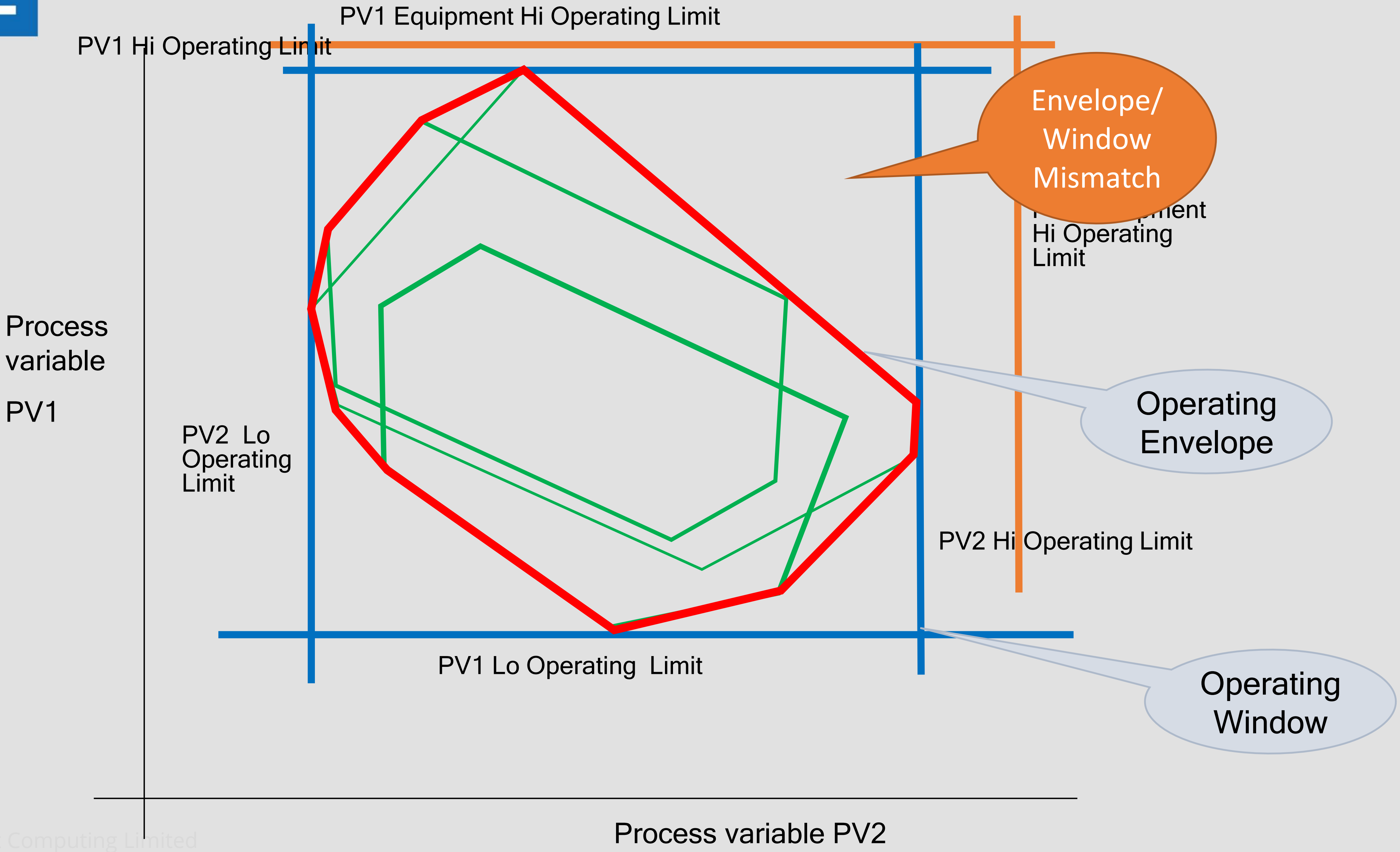


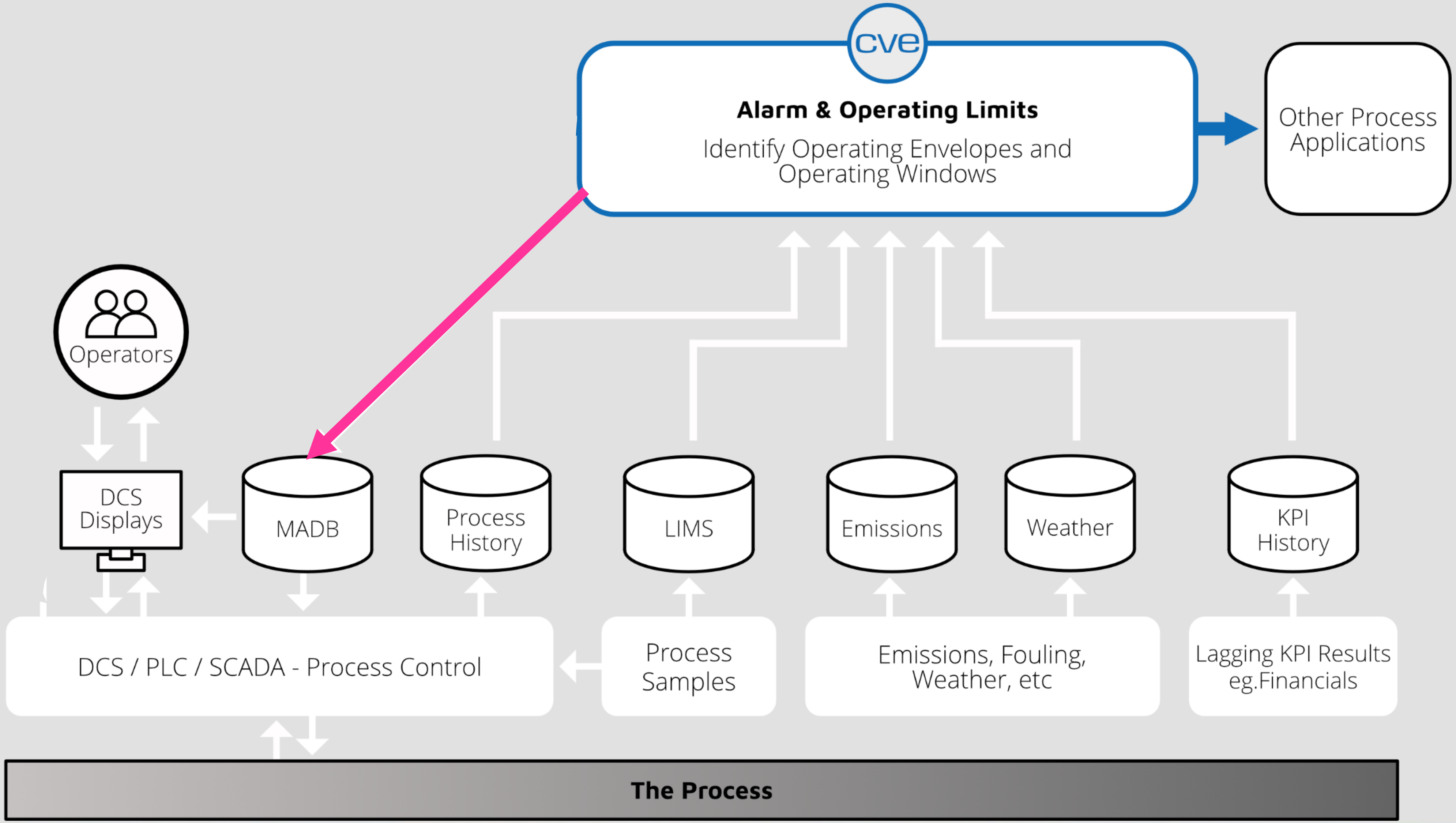
# Intersections Change with Time



# Operating Limits – Operating Windows – Operating Envelopes



# Linking Operations and Outcomes through Operating Envelopes



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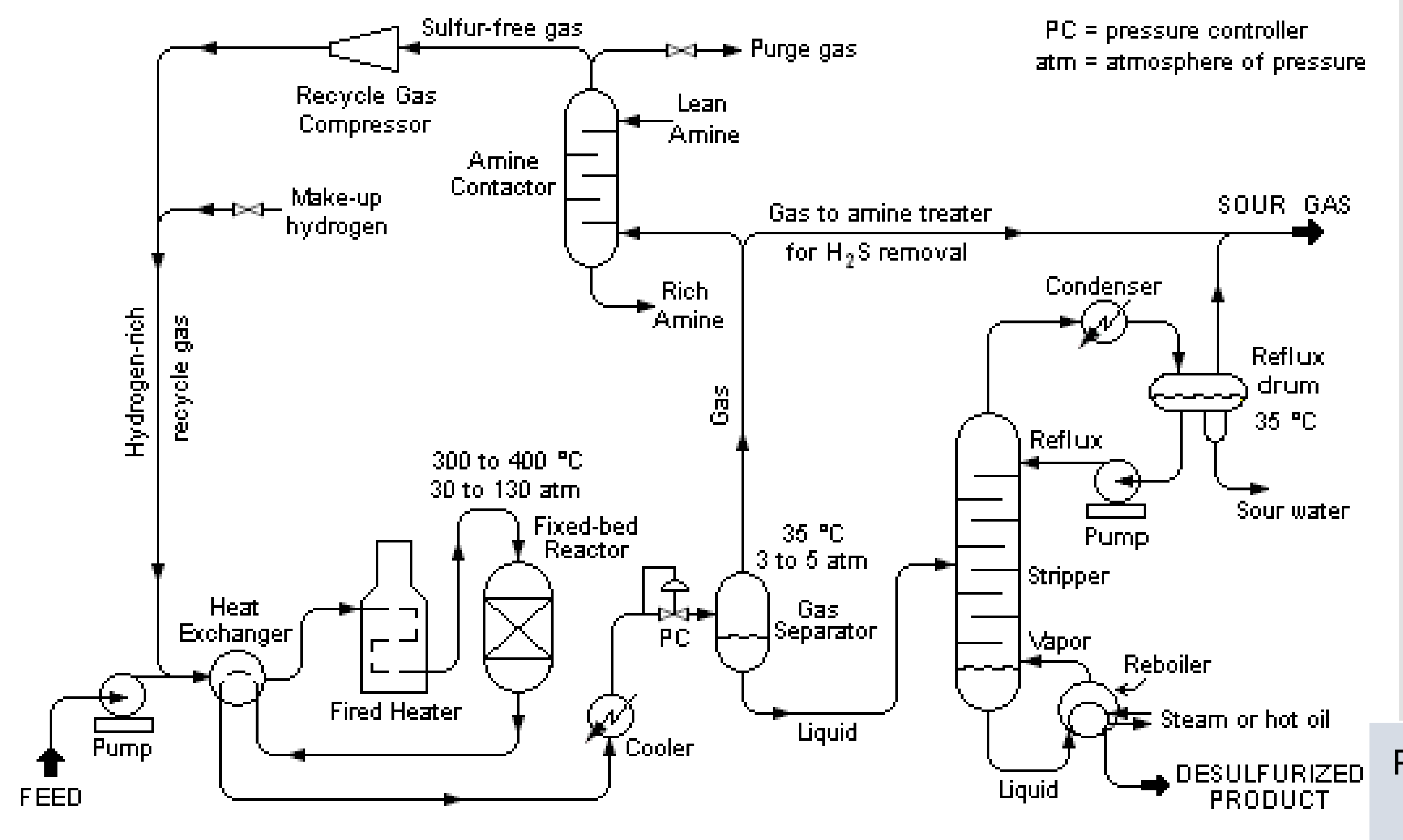
# HDS Schematic




Product Specs

# Where does it start?

Process History Data import (csv, Excel, PI, PHD) …..

TAMU.ves.csv

| | W | X | Y | Z | AA | AB | AC | AD | AE | AF | AG | AH | AI | AJ | AK | AL | AM | AN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M3/HR | KNM3/HR | M3/HR | M3/HR | M3/HR | M3/HR | L/HR | NM3/HR | M3/HR | KNM3/HR | TONNE/H | M3/HR | KNM3/HR | KNM3/HR | KNM3/HR | M3/HR | DEGC | KNM3/ |
| 2 | GAS OIL F | H2 M/U G | PUMP 030 | REBLR FUF | REBLR FUF | LCCO PUM | HDS LUBR | 0300 Exch | Raw HCN | SCRUBBER | LP SEPRTR | STRIPPER | FUEL GAS | FUEL GAS | FUEL GAS | LCCO PUM | REACTR 2 | RECYCL |
| 3 | N03FC379 | N03FC380 | N03FC506 | N03FC516 | N03FC517 | N03FC540 | N03FC552 | N03FC565 | N03FC582 | N03FI095_ | N03FI098_ | N03FI122_ | N03FI1533 | N03FI162_ | N03FI164_ | N03FI540_ | N03FI95_F | N03FR0 |
| 4 | 1.94365 | 3.39589 | 6.2016 | 0 | -4.38871 | 37.7543 | 0.068464 | 2841.42 | 0.00807 | -6.81E-06 | 0.246832 | 172.348 | 3.59E-06 | 1.12695 | 0.890049 | 37.8094 | 506.497 | 28.57 |
| 5 | 2.05572 | 3.56238 | 6.05197 | 0 | -4.38871 | 37.5725 | 0.068464 | 2844.85 | 0.00134 | -6.81E-06 | 0.249863 | 179.596 | 3.59E-06 | 1.12304 | 0.890181 | 37.4313 | 506.002 | 28.68 |
| 6 | 2.5549 | 3.64624 | 6.15486 | 0 | -4.38871 | 36.4718 | 0.068464 | 2842.36 | 0.00807 | -6.81E-06 | 0.249955 | 175.057 | 3.59E-06 | 1.11545 | 0.878297 | 36.5844 | 505.892 | 28.68 |
| 7 | 2.05572 | 3.67029 | 6.21854 | 0 | -4.38871 | 36.5357 | 0.068464 | 2844.22 | 0.00807 | -6.81E-06 | 0.251828 | 179.174 | 3.59E-06 | 1.11669 | 0.868948 | 36.7217 | 506.356 | 28.76 |
| 8 | 2.44284 | 3.7123 | 6.06865 | 0 | -4.38871 | 36.4884 | 0.068464 | 2840.14 | 0.00807 | -6.81E-06 | 0.25245 | 177.366 | 3.59E-06 | 1.1079 | 0.867556 | 36.634 | 506.171 | 28.57 |

| | W | X | Y | Z | AA |
|---|---|---|---|---|---|
| 9 | 2.66696 | 3.67363 | 6.00893 | 0 | -4.3887 |
| 10 | 3.4412 | 3.61907 | 6.02294 | 0 | -4.3887 |
| 11 | 2.44284 | 3.6598 | 5.96589 | 0 | -4.3887 |
| 12 | 2.94202 | 3.65797 | 6.07973 | 0 | -4.3887 |
| 13 | 3.4412 | 3.64802 | 6.08674 | 0 | -4.3887 |
| 14 | 2.44284 | 3.64035 | 6.12914 | 0 | -4.3887 |
| 15 | 3.05408 | 3.58685 | 6.18657 | 0 | -4.3887 |
| 16 | 2.44284 | 3.52842 | 6.13525 | 0 | -4.3887 |
| 17 | 2.44284 | 3.40353 | 6.09514 | 0 | -4.3887 |
| 18 | 2.5549 | 3.1653 | 6.08954 | 0 | -4.3887 |
| 19 | 2.44284 | 2.91333 | 6.11997 | 0 | -4.3887 |
| 20 | 2.44284 | 2.71963 | 6.05197 | 0 | -4.3887 |
| 21 | 2.66696 | 2.77103 | 6.16785 | 0 | -4.3887 |
| 22 | 2.44284 | 2.83438 | 6.10552 | 0 | -4.3887 |
| 23 | 4.05244 | 2.96717 | 6.12914 | 0 | -4.3887 |
| 24 | 2.94202 | 3.12387 | 6.17206 | 0 | -4.3887 |

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | DateTime | Bulk Density (kg/L) | Coating Agent (%w/w) | Friability (%w/w) | Moisture (%w/w) | Oil Absorption (%w/w) | Product Less 1mm (%w/w) |
| 2 | 01/07/2005 00:00 | 0.773 | 0.08 | 1.05 | 0.119999997 | 7.2 | 0.119999997 |
| 3 | 01/07/2005 06:00 | 0.79 | 0.08 | 1.84 | 0.140000001 | 6 | 0.439999998 |
| 4 | 01/07/2005 21:00 | 0.765 | 0.08 | 2.01 | 0.209999993 | 7.3 | 0.189999998 |
| 5 | 02/07/2005 03:00 | 0.738 | 0.08 | 1.2 | 0.119999997 | 7.4 | 0.209999993 |
| 6 | 02/07/2005 06:00 | 0.76 | 0.08 | 1.3 | 0.119999997 | 7.9 | 0.170000002 |
| 7 | 02/07/2005 09:00 | 0.728 | 0.08 | 1.2 | 0.119999997 | 8.7 | 0.159999996 |
| 8 | 02/07/2005 12:00 | 0.765 | 0.19 | 1.35 | 0.119999997 | 8 | 0.05 |
| 9 | 02/07/2005 18:00 | 0.762 | 0.08 | 1.57 | 0.109999999 | 7.6 | 0.05 |
| 10 | 02/07/2005 21:00 | 0.774 | 0.08 | 1.09 | 0.100000001 | 6.5 | 0.07 |
| 11 | 03/07/2005 00:00 | 0.774 | 0.09 | 1.15 | 0.109999999 | 7.5 | 0.05 |
| 12 | 03/07/2005 03:00 | 0.773 | 0.09 | 1.42 | 0.109999999 | 7.6 | 0.09 |
| 13 | 03/07/2005 09:00 | 0.754 | 0.07 | 1.82 | 0.159999996 | 8 | 0.170000002 |
| 14 | 03/07/2005 12:00 | 0.767 | 0.08 | 0.94 | 0.109999999 | 8 | 0.100000001 |
| 15 | 03/07/2005 15:00 | 0.763 | 0.08 | 1.02 | 0.119999997 | 8 | 0.109999999 |
| 16 | 03/07/2005 18:00 | 0.77 | 0.08 | 1.52 | 0.119999997 | 8 | 0.07 |
| 17 | 03/07/2005 21:00 | 0.771 | 0.08 | 1.17 | 0.119999997 | 8 | 0.05 |
| 18 | 04/07/2005 00:00 | 0.768 | 0.07 | 1 | 0.119999997 | 8.1 | 0.03 |
| 19 | 04/07/2005 03:00 | 0.77 | 0.08 | 1.05 | 0.119999997 | 8.1 | 0.04 |
| 20 | 04/07/2005 06:00 | 0.771 | 0.07 | 1.17 | 0.119999997 | 8.1 | 0.07 |
| 21 | 04/07/2005 12:00 | 0.765 | 0.08 | 1.44 | 0.129999995 | | 0.08 |
| 22 | 04/07/2005 15:00 | 0.764 | 0.09 | 1.24 | 0.129999995 | 8.7 | 0.09 |

Laboratory Quality Results,
Lagging and Leading KPI History

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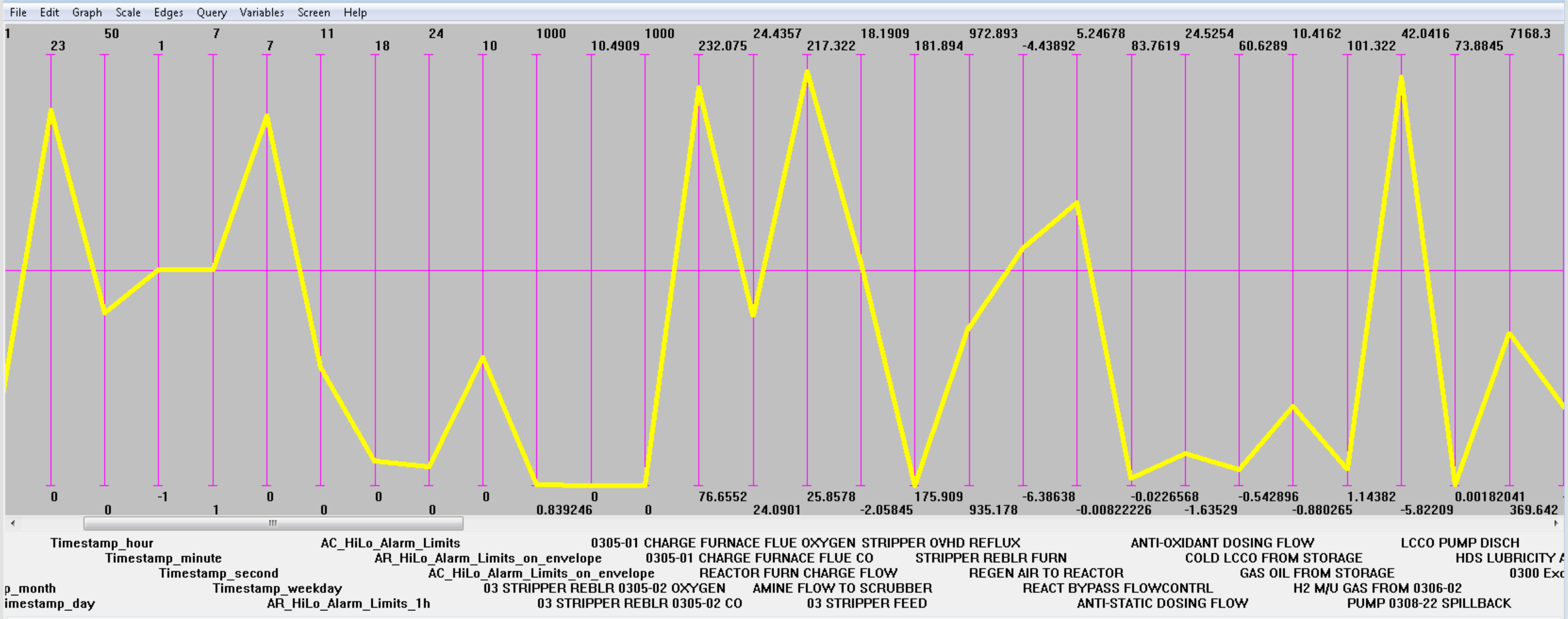
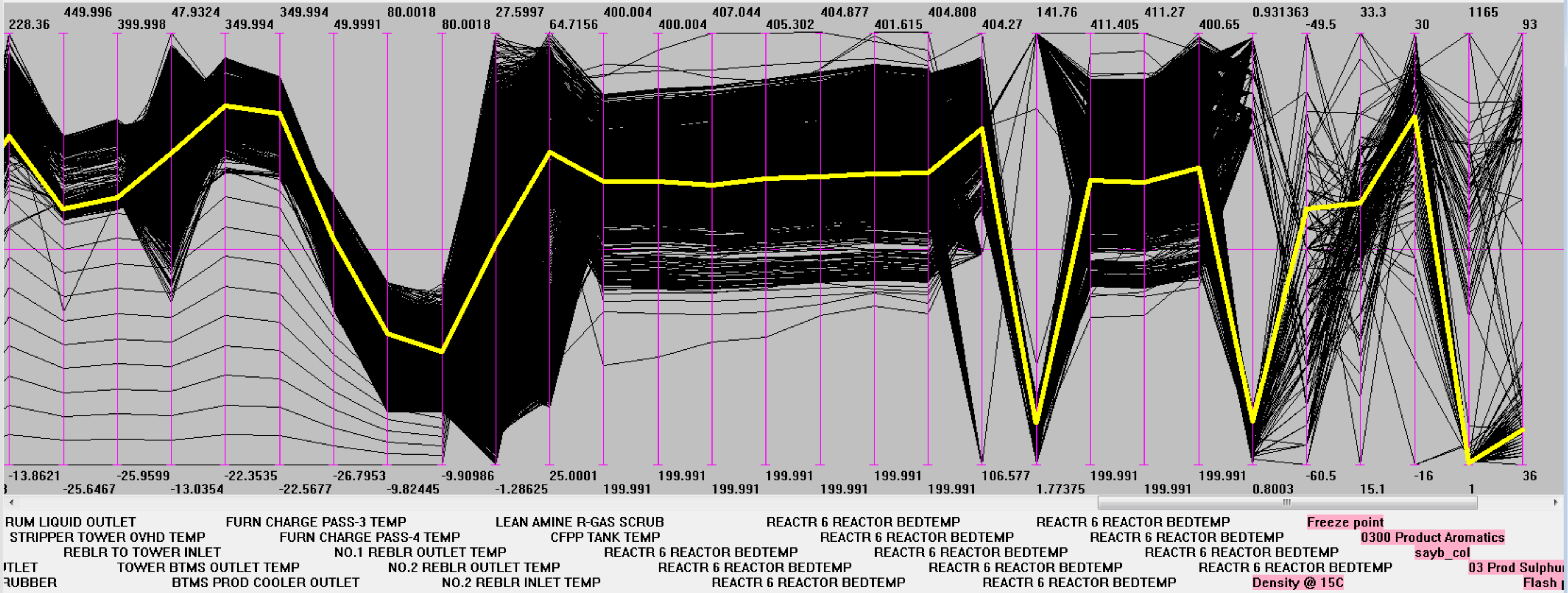
# Visualizing an Operating Envelope: Snapshot



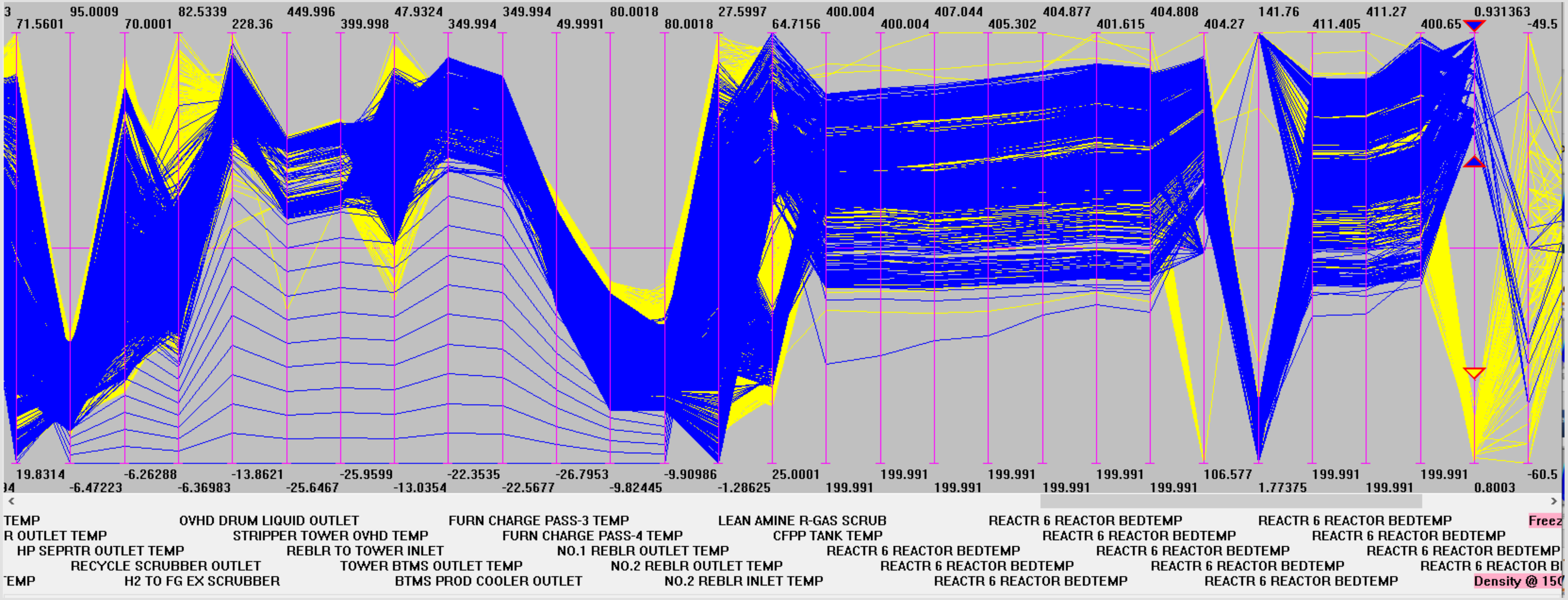

- Graph axes are the vertical pink lines – one variable per axis
- Poly-line represents one row of an excel sheet or one moment in time or one process operating point

# Visualizing the Normal Operating Envelope




- Each polyline line still represents one point in time but here there are 10,262 polylines
- Links data from left (process causes) to right (results and KPIs in pink)
- Patterns and density capture process behaviour and variable relationships

# Visualizing Two Operating Envelopes




- Two different modes, one for kerosene and one for gas oil, highlighted

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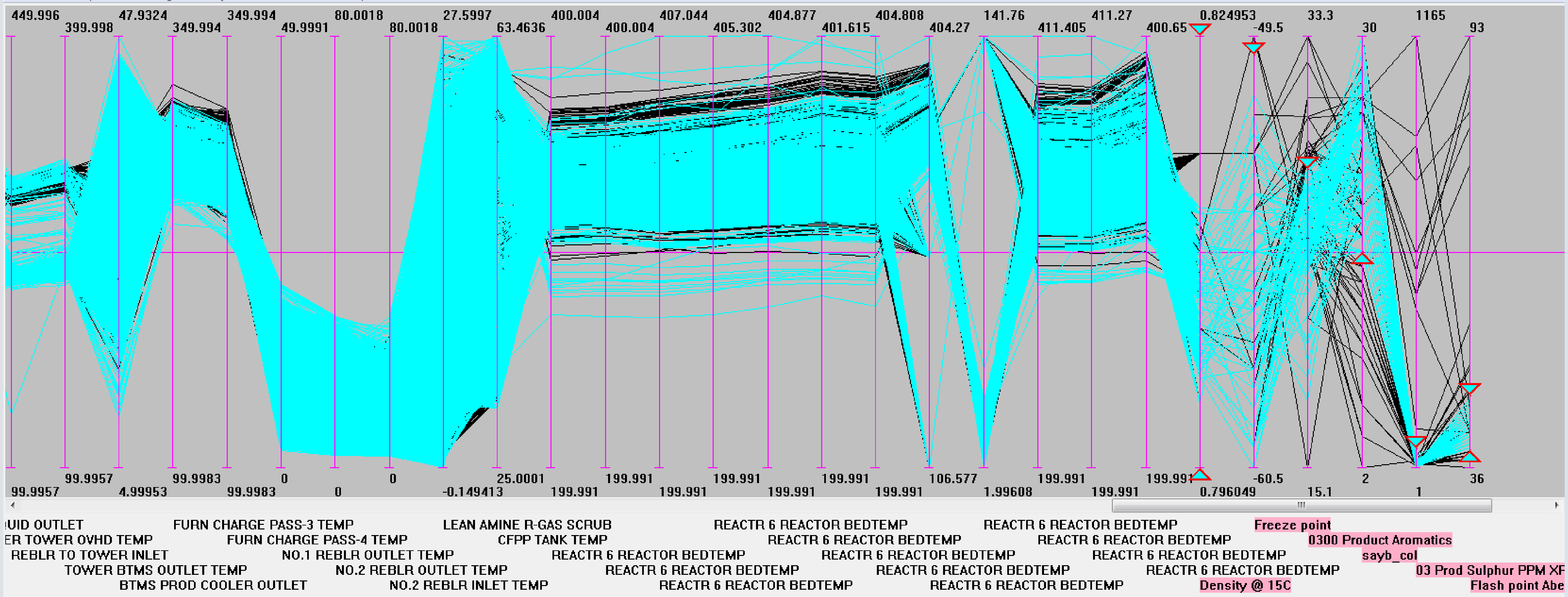
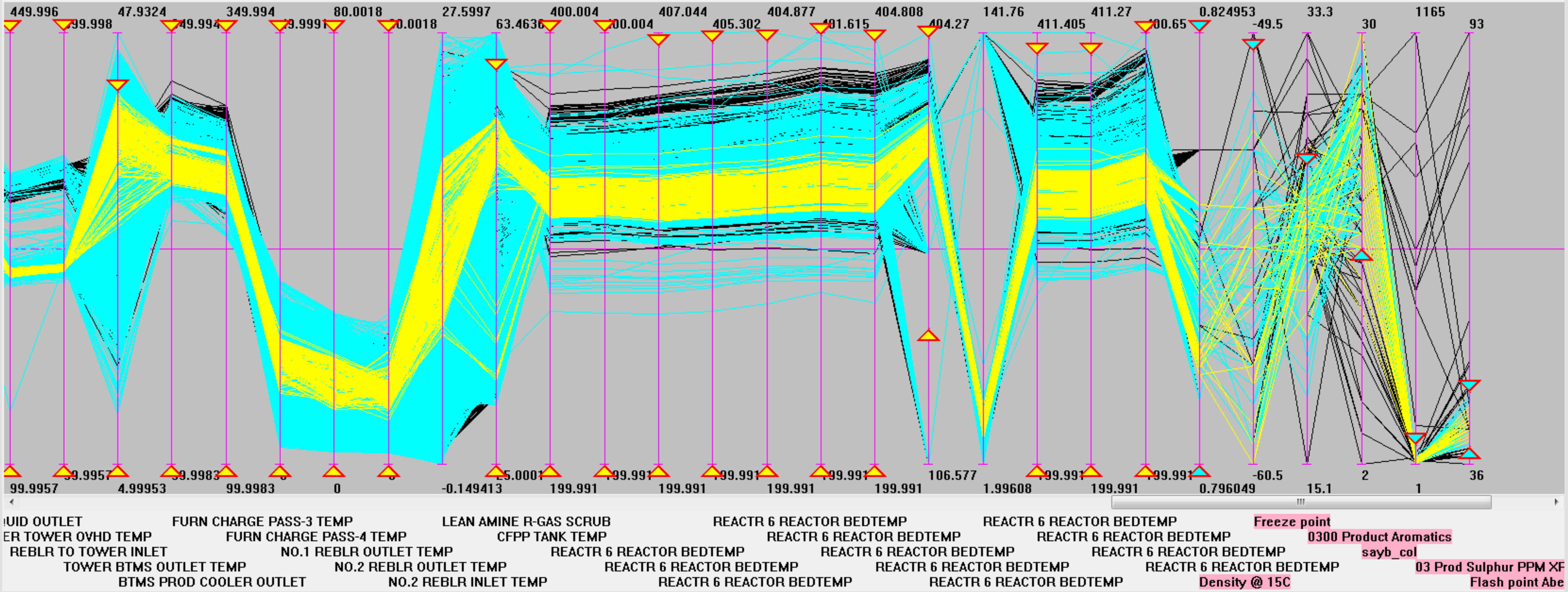
# Lagging KPI Operating Envelope



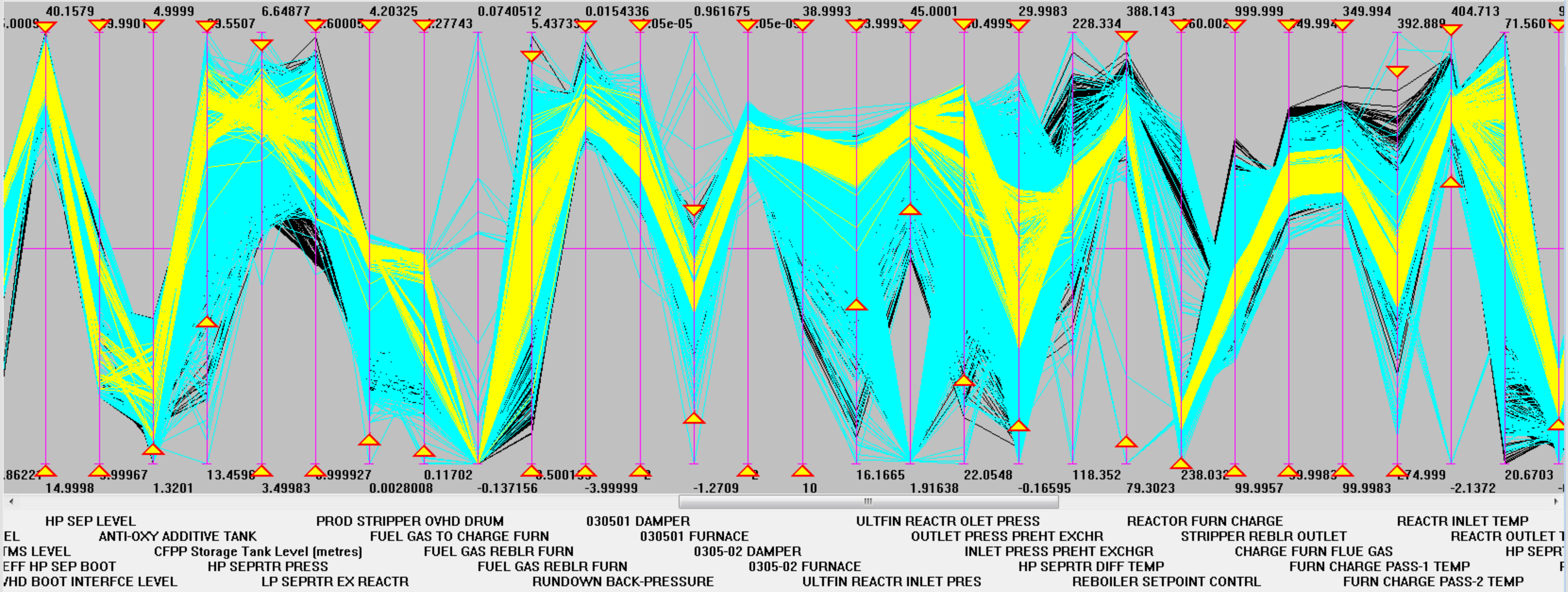

- HDS Unit showing part of an envelope for achievement of the lagging KPI of in-specification kerosene in blue and out of spec in black. 82% was in specification

# Alarms and Operating Envelopes



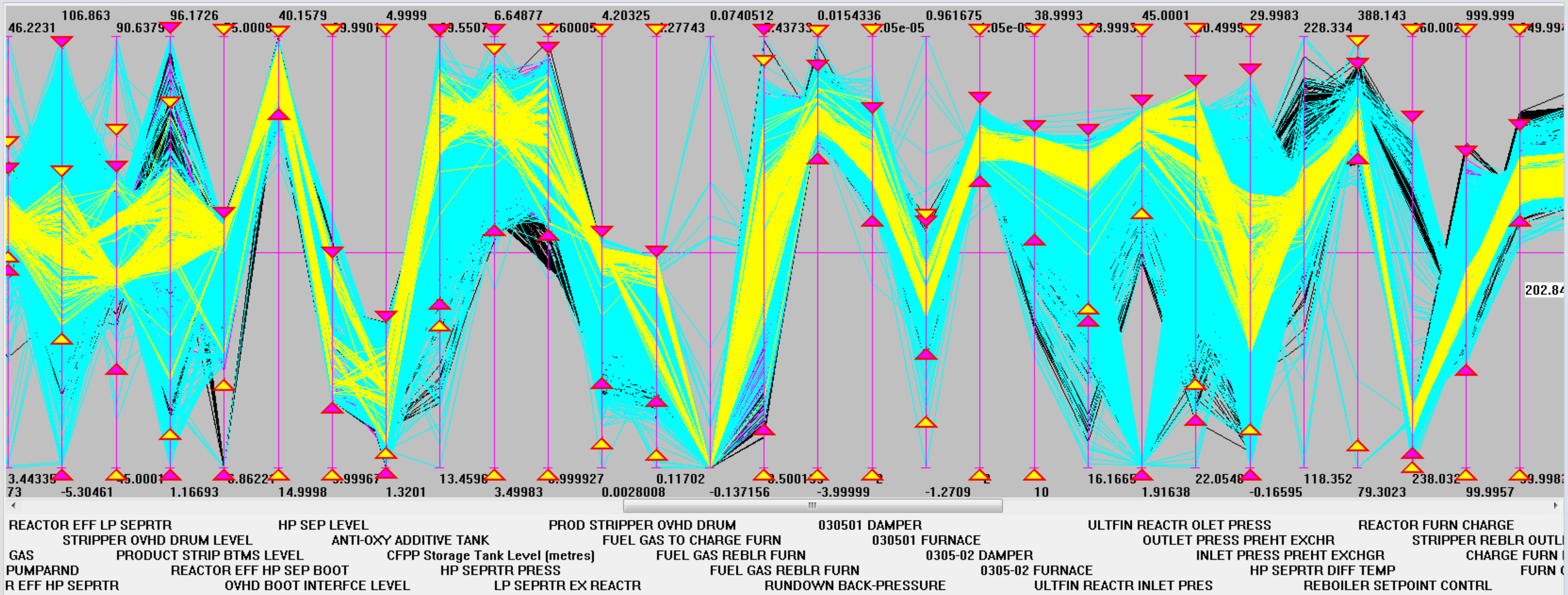

- Current Alarm limits added as yellow triangles. Those inside the envelope are current “bad actors.” Those outside may never annunciate and don’t help the operator.
- Yellow shows 3% of operation was inside all alarm limits. That’s the Clean Board Rate.

# Alarms and Operating Envelopes - 2



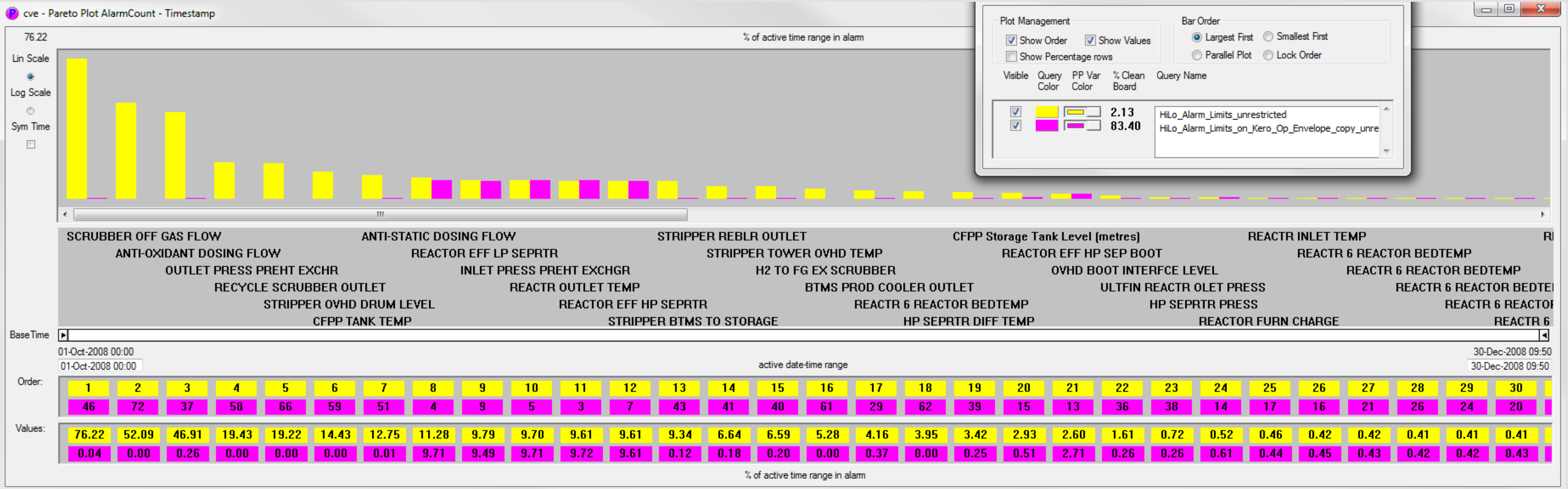

- Current Alarm limits added as yellow triangles. Those inside the blue area will give False Alarms. Those outside may never annunciate and don’t help the operator
- Yellow shows 3% of operation was inside all alarm limits. That’s the Clean Board Rate.

# Hi Lo Alarm Limits on the Operating Envelope



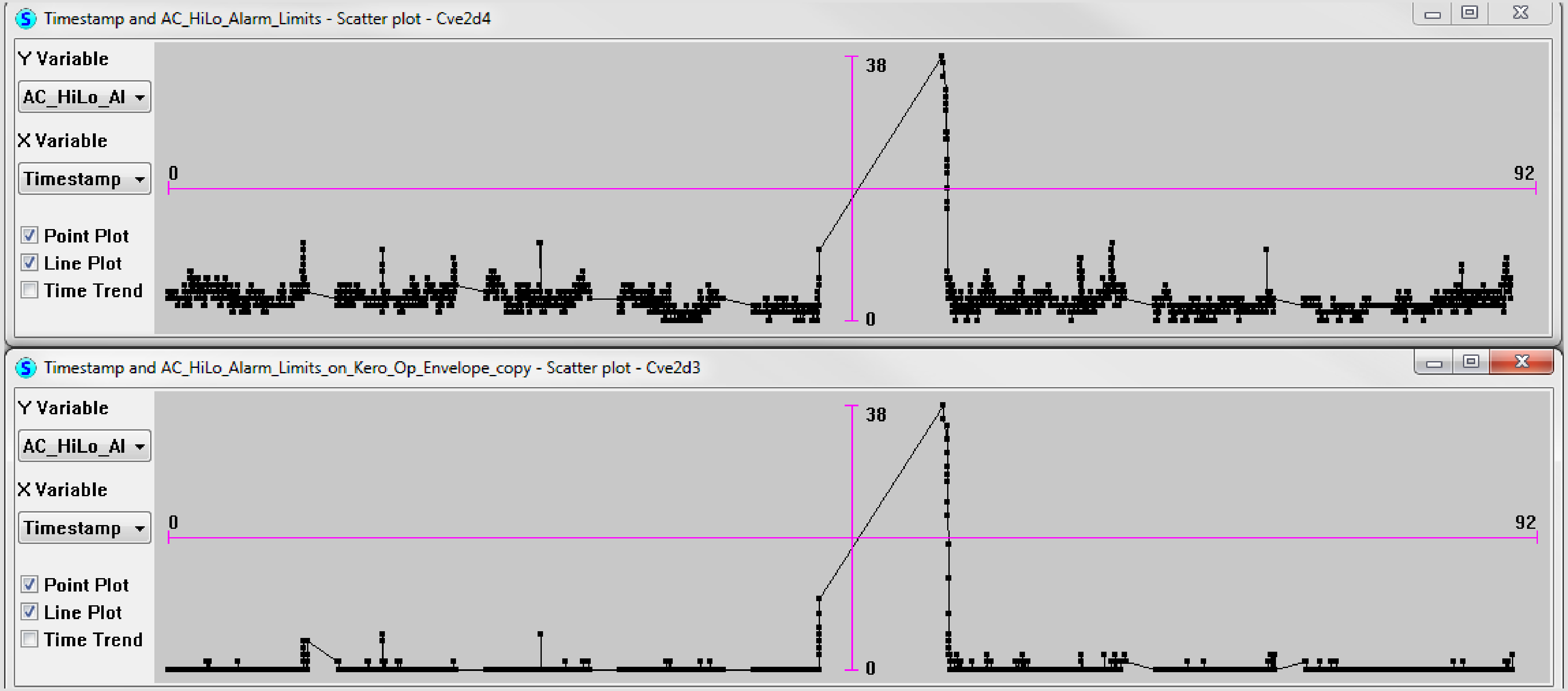

- Magenta are the alarm limits repositioned to the extreme boundary of the Lagging KPI operating envelope. Notice those that were outside have moved in and those that were inside have moved out.
- The pink envelope is underneath the blue. Where pink can be seen would be out-of-specification kerosene. Operating in the pink envelope raises the yield of in-spec kerosene from 82% to 86%

# Alarm Performance Prediction



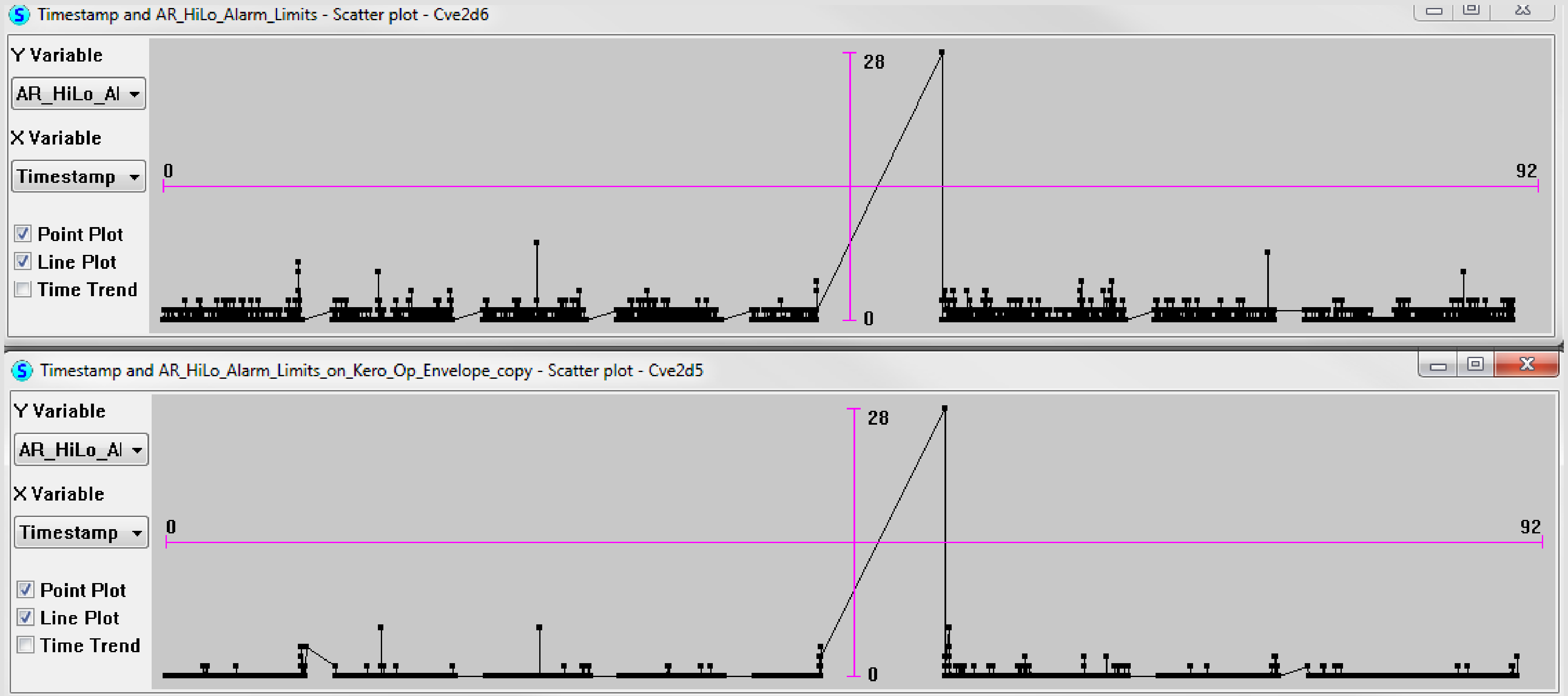

- Alarm performance improves dramatically. Original alarms in yellow, proposed new alarms in magenta.
- "Clean Board" percent (ie. no alarms present in alarm list) rises from **3% to 83% of time.** The span of the data is 3 months.
- Scroll right to see the "always silent" alarms

# Alarms Before and After – Alarm Count in the Alarm List Display




- Number of alarms in the alarm list display before (top) and after (bottom).
- Fewer alarms get more attention and earlier action.

## Alarms Before and After – Annunciations per hour




- Alarm Annunciations/hour before (top) and after (bottom).
- Fewer alarms will get more attention and earlier action.

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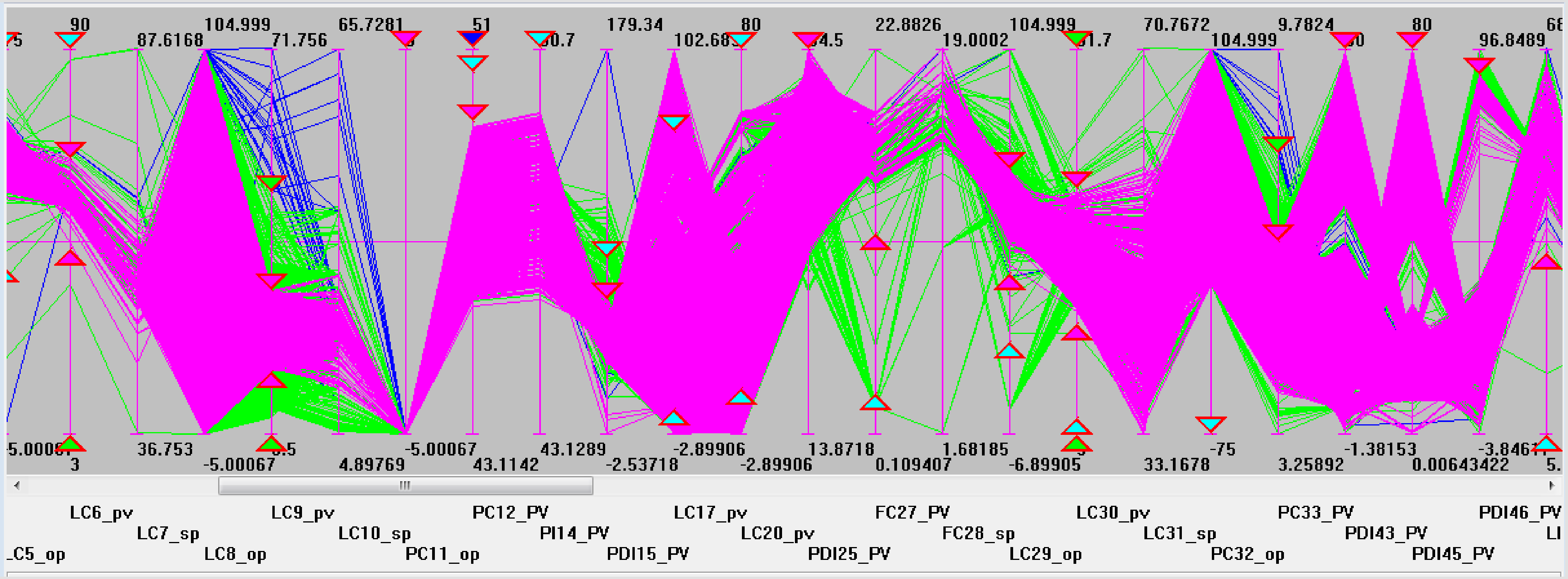
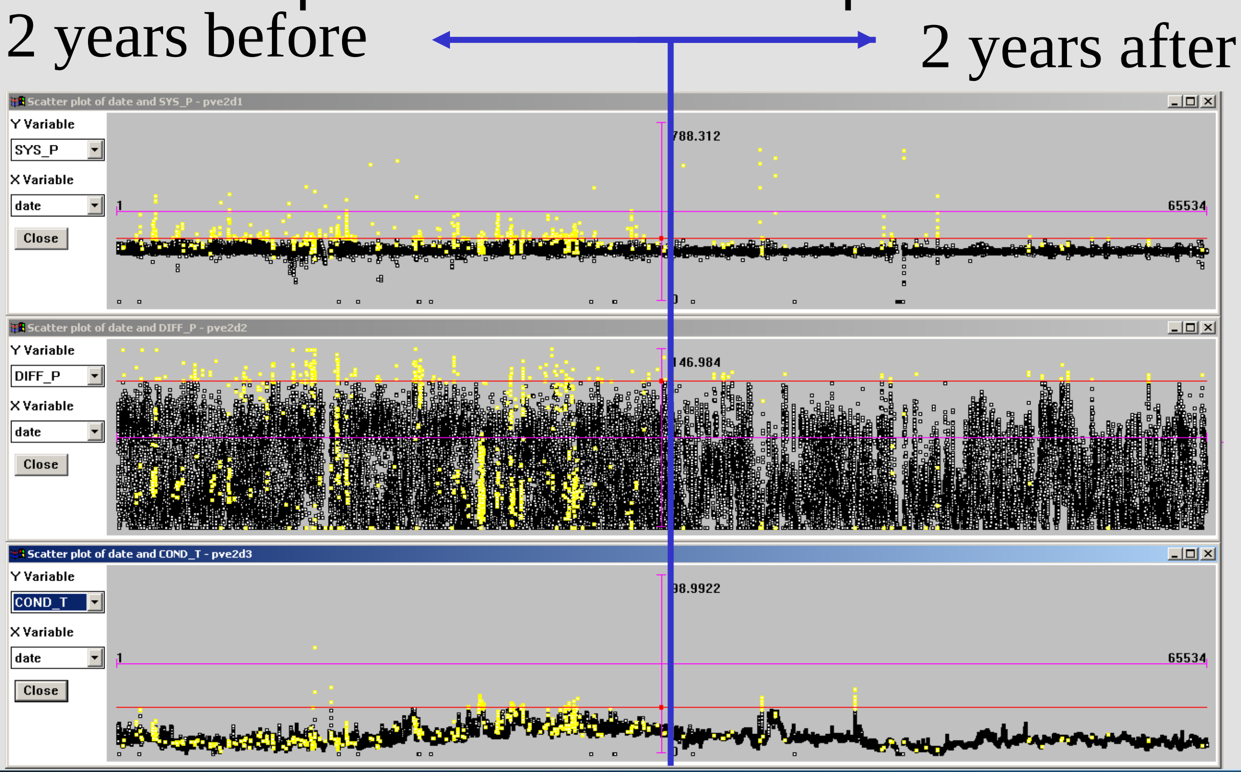
# Many Sets of Limits




- The picture is a bit more complicated, this image shows may levels
    - Blue Trip levels, Green HH/LL, Maroon HI/LO, Cyan as-found HI/LO
- These can be brought into one picture, and evaluated together

# Improved Alarm Performance

- Alarms repositioned to boundaries of no-trips envelope
- Operators presented with tighter limits in some cases, but relevant alarms
- Process went from 98% uptime to 99.9% uptime after rationalization



# Dynamic Predictive Alarms and Alerts

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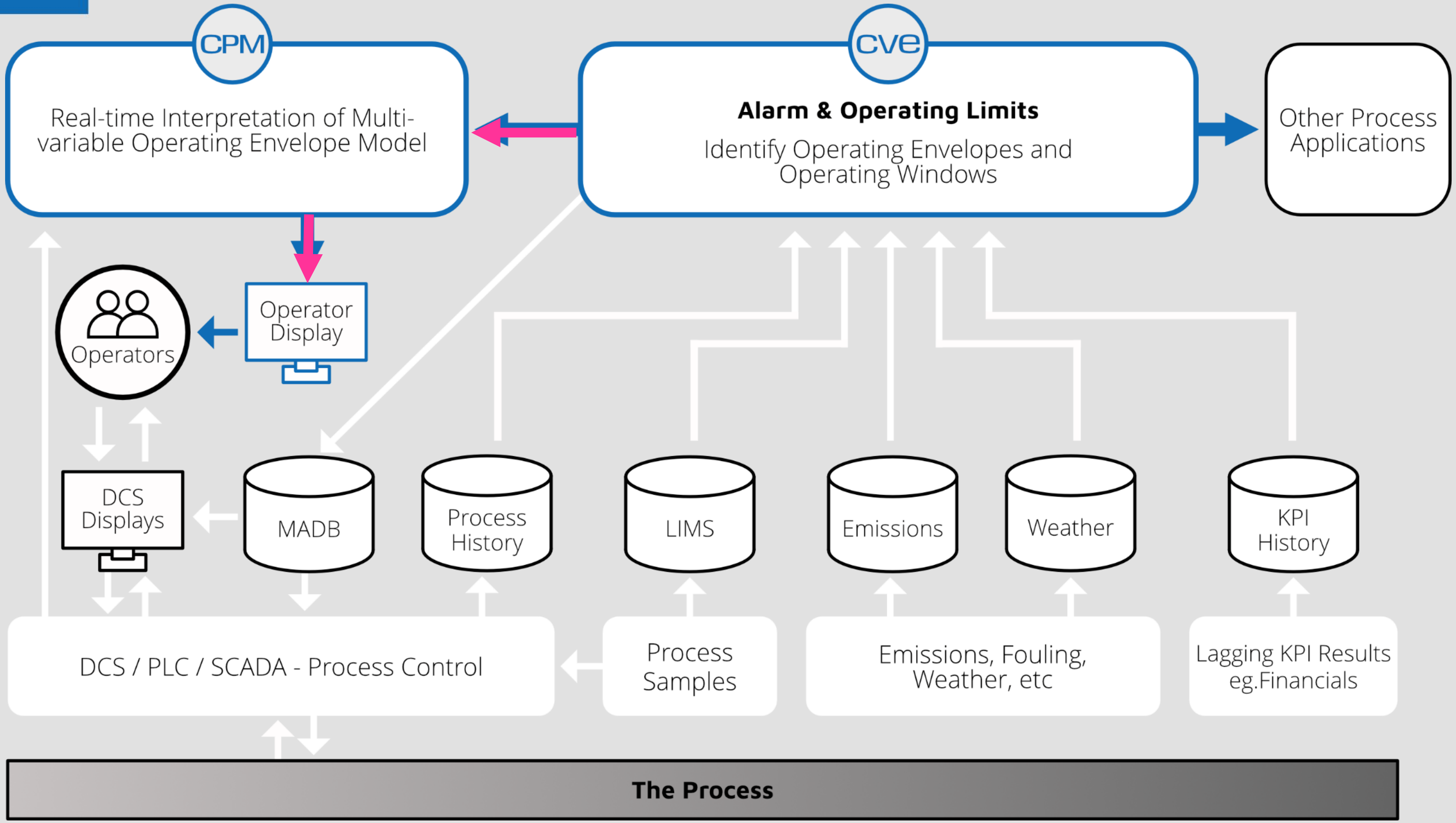
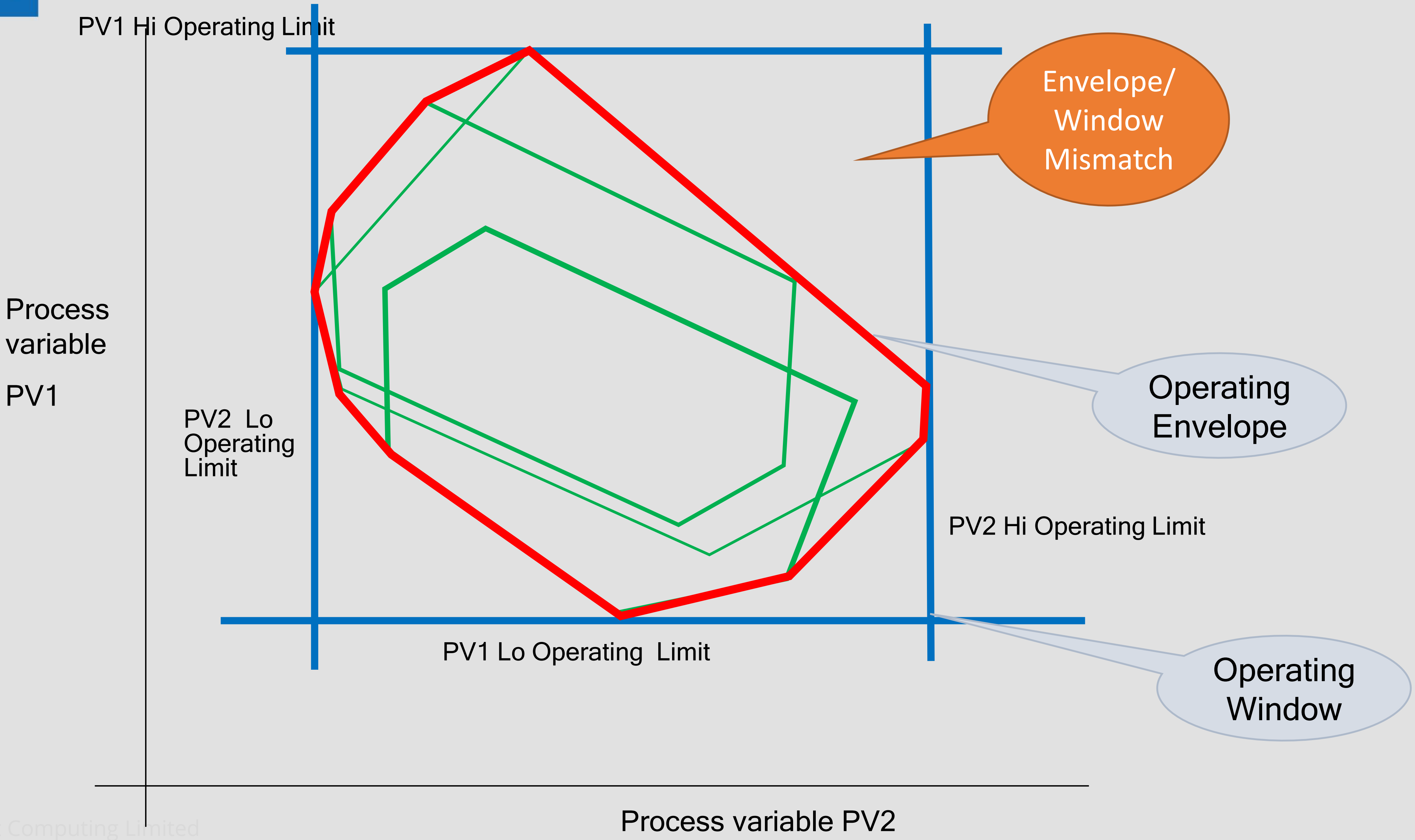
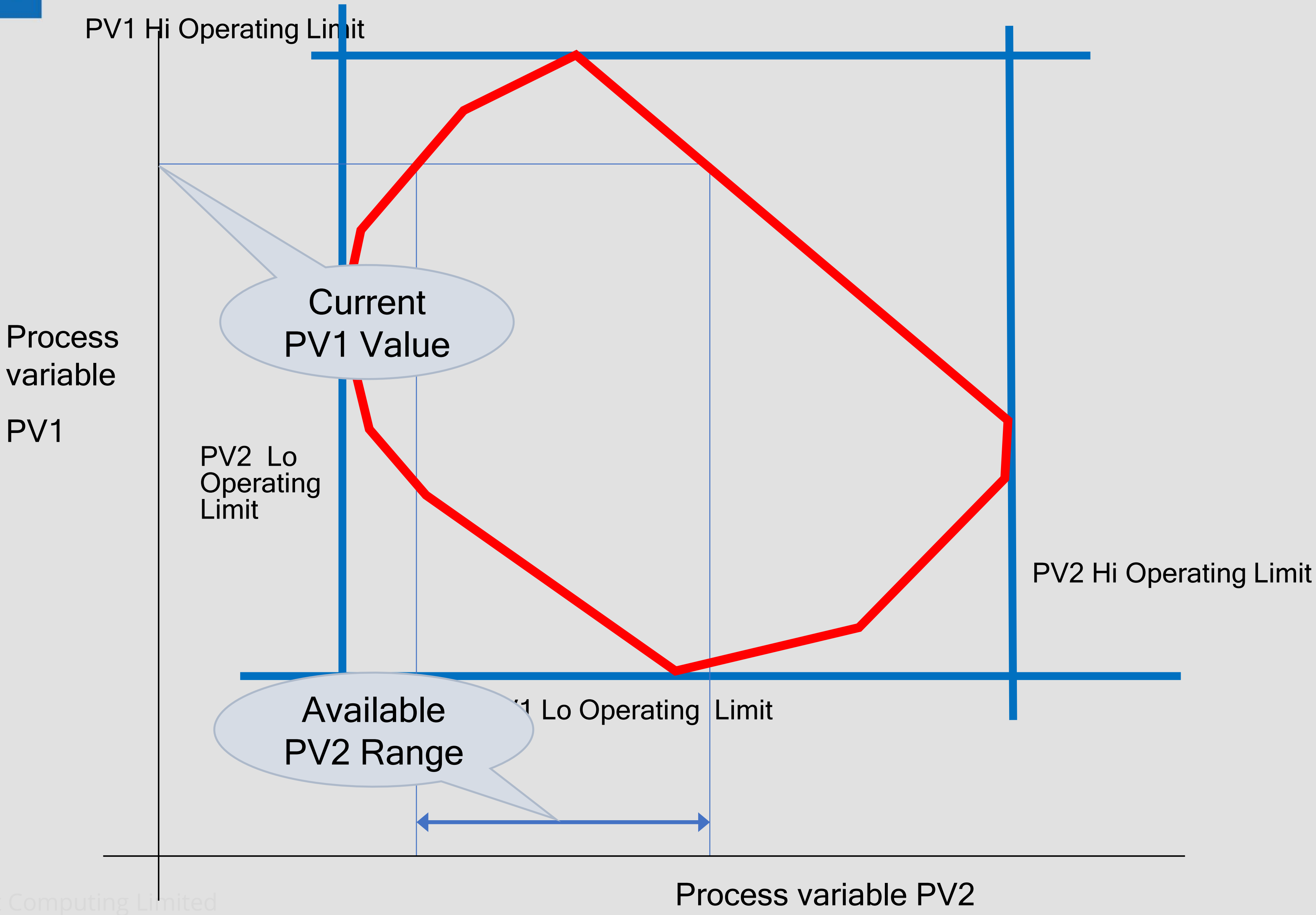
# Dynamic Alarms from Operating Envelopes



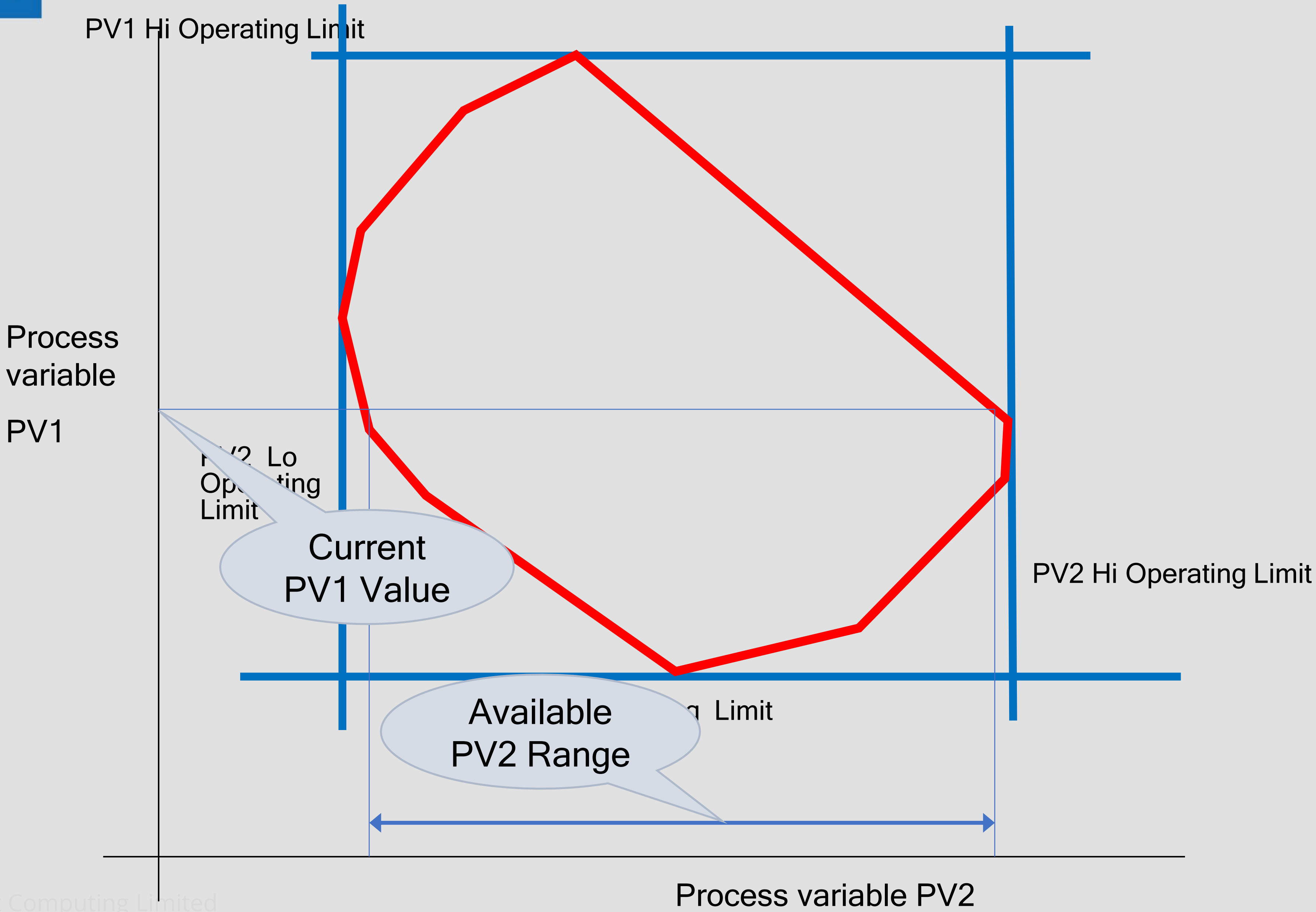
# Operating Limits – Operating Windows – Operating Envelopes



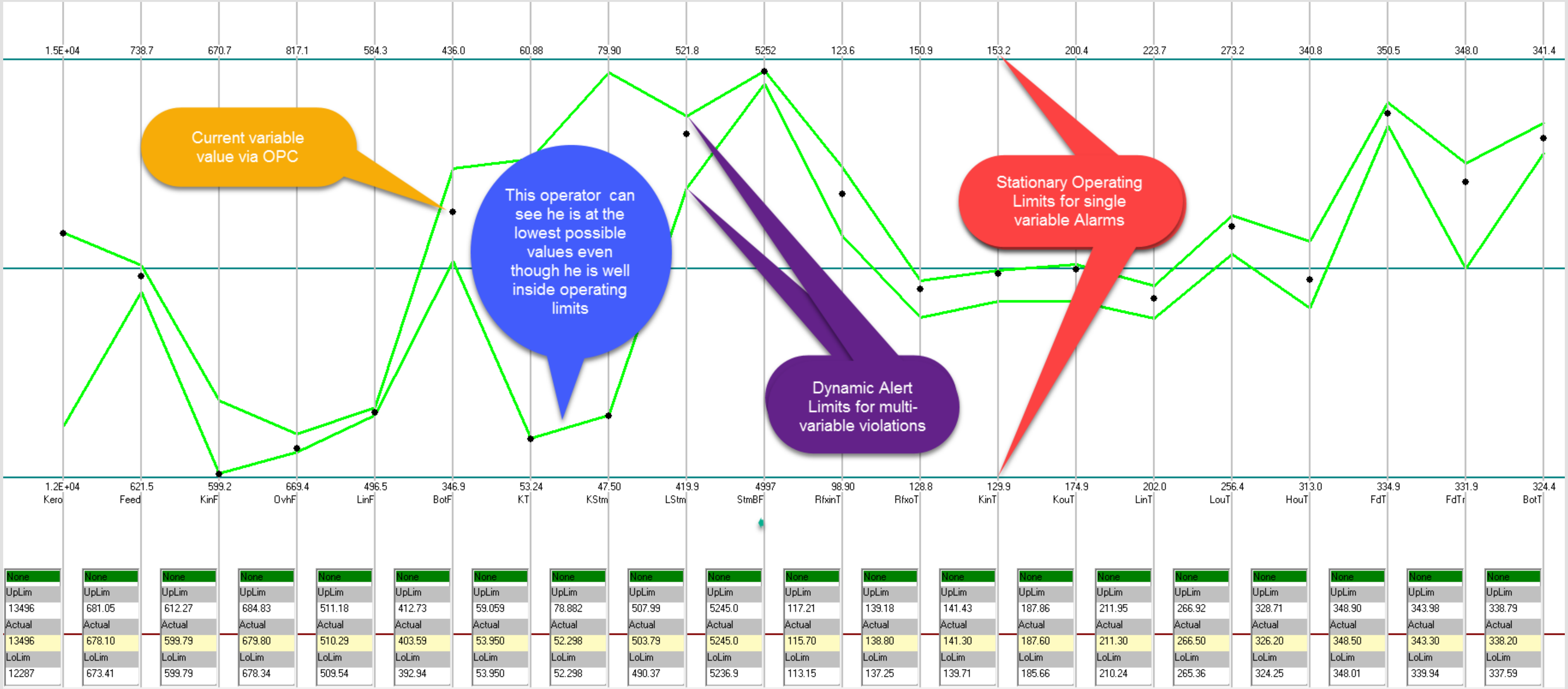
# CPM: Dynamic Ranges from Operating Envelope



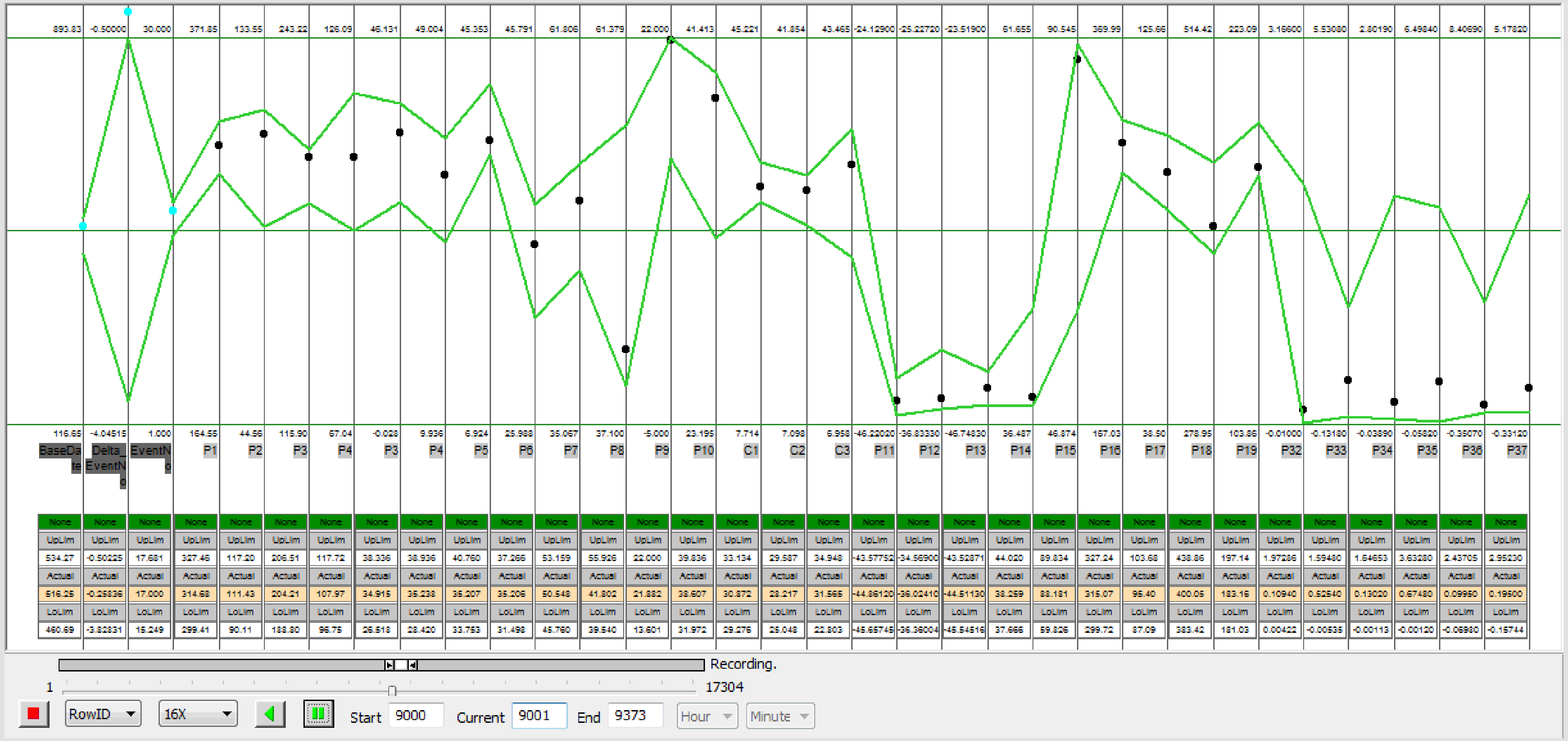
# CPM: Dynamic Ranges from Operating Envelope



# CPM Operator Display



# Early Surge Warning




- Operator alerts begin two hours before event
- Alerts point to the variables that are key in understanding the event
- Opportunity for operator to avoid or mitigate the process impacts

## Summary

- New method for visualizing operating envelopes and alarms
- Bring operations into the alarm review, no more “Wait-and-see”
- Alarms positioned on the operating envelope enable operator performance
- Efficient alarm review
- Natural progression to dynamic and predictive alarming

# THANK YOU FOR YOUR TIME TODAY

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