Industry 4.0 - Remote Monitoring

Health of Semiconductor Manufacturing Factories Using Splunk Log Analytics

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Applied Materials AGS

Our innovations **make possible**
the technology shaping the future

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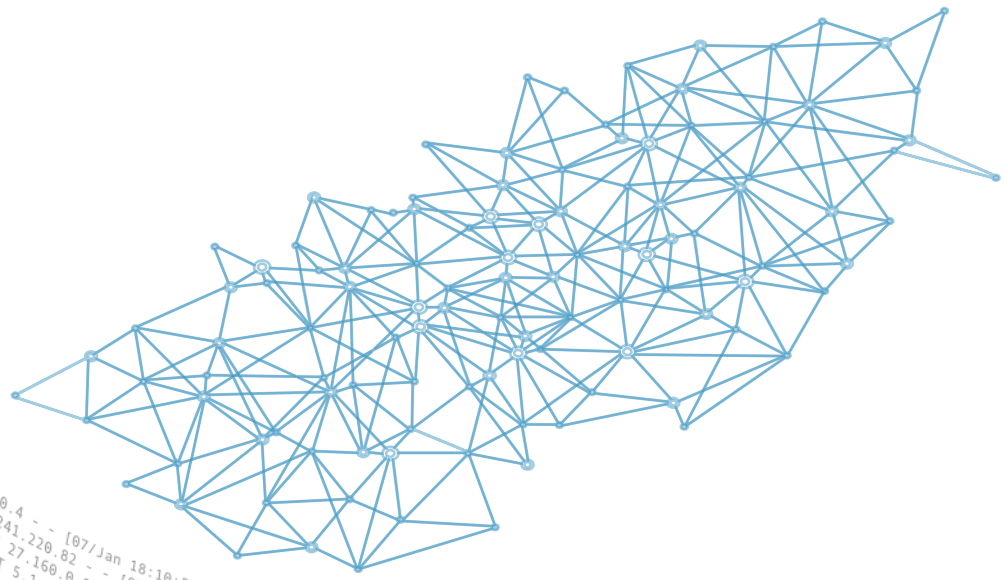
THE MOST EXCITING Industries on Earth



Applied Materials is the leader in materials engineering solutions used to produce virtually every new chip and advanced display in the world

Our expertise in modifying materials at atomic levels and on an industrial scale enables customers to transform possibilities into reality

At Applied Materials, our innovations make possible the technology shaping the future

What Others Are Saying

Newsweek GREEN RANKINGS

FORTUNE WORLD'S MOST ADMIRED COMPANIES® 2018

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Supplier Awards

intel 2017 PREFERRED QUALITY SUPPLIER AWARD

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2018 WORLD'S MOST ETHICAL COMPANIES® ™

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CR's 100 Best Corporate Citizens 2017

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World's #1

semiconductor and display equipment company

$14.5 billion
revenue

$1.8 billion
R&D spending

>11,900
patents

AMAT stock listing on NASDAQ

Headquartered in California's **Silicon Valley**

~18,400 employees
90 locations
In **17** countries

Data as of fiscal year end, October 29, 2017

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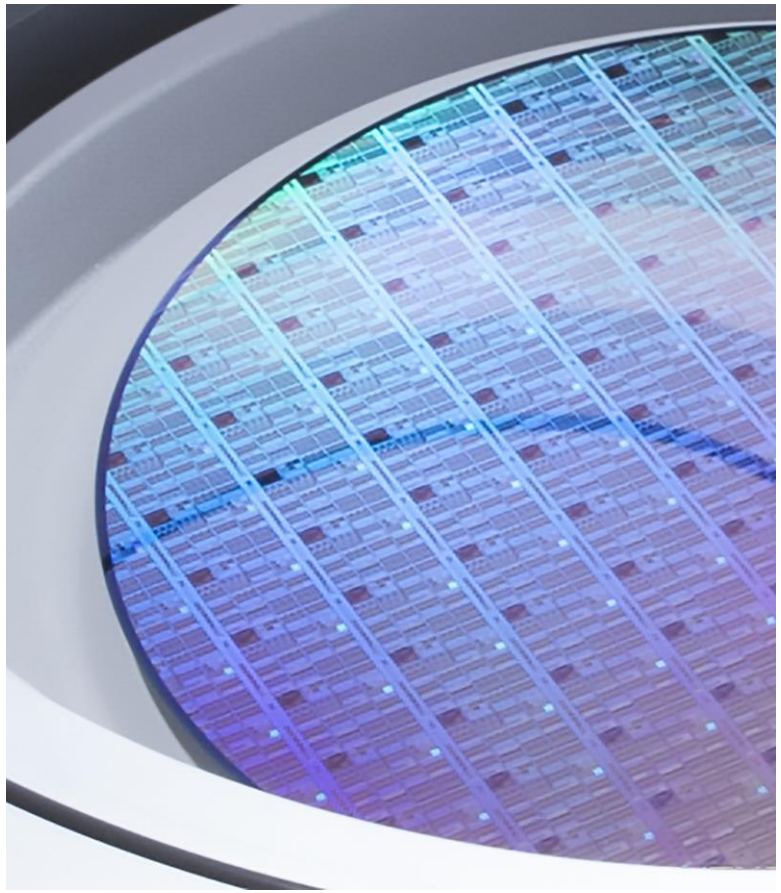
Businesses

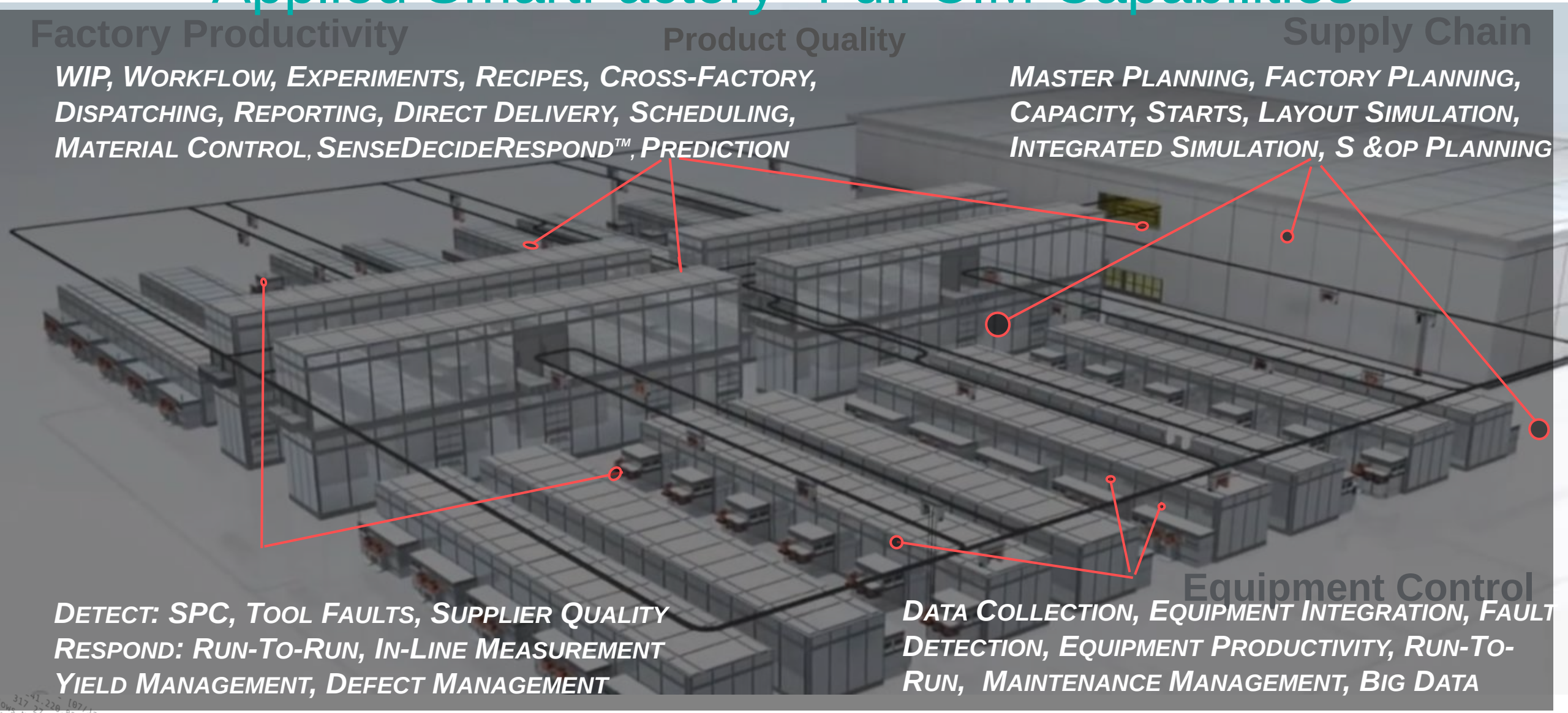


Semiconductor Systems

Applied Global Services

Display and Adjacent Markets

Applied SmartFactory® Full CIM Capabilities



Factory Productivity

WIP, Workflow, Experiments, Recipes, Cross-Factory, Dispatching, Reporting, Direct Delivery, Scheduling, Material Control, SenseDecideRespond™, Prediction

Product Quality

Detect: SPC, Tool Faults, Supplier Quality
Respond: Run-To-Run, In-Line Measurement
Yield Management, Defect Management

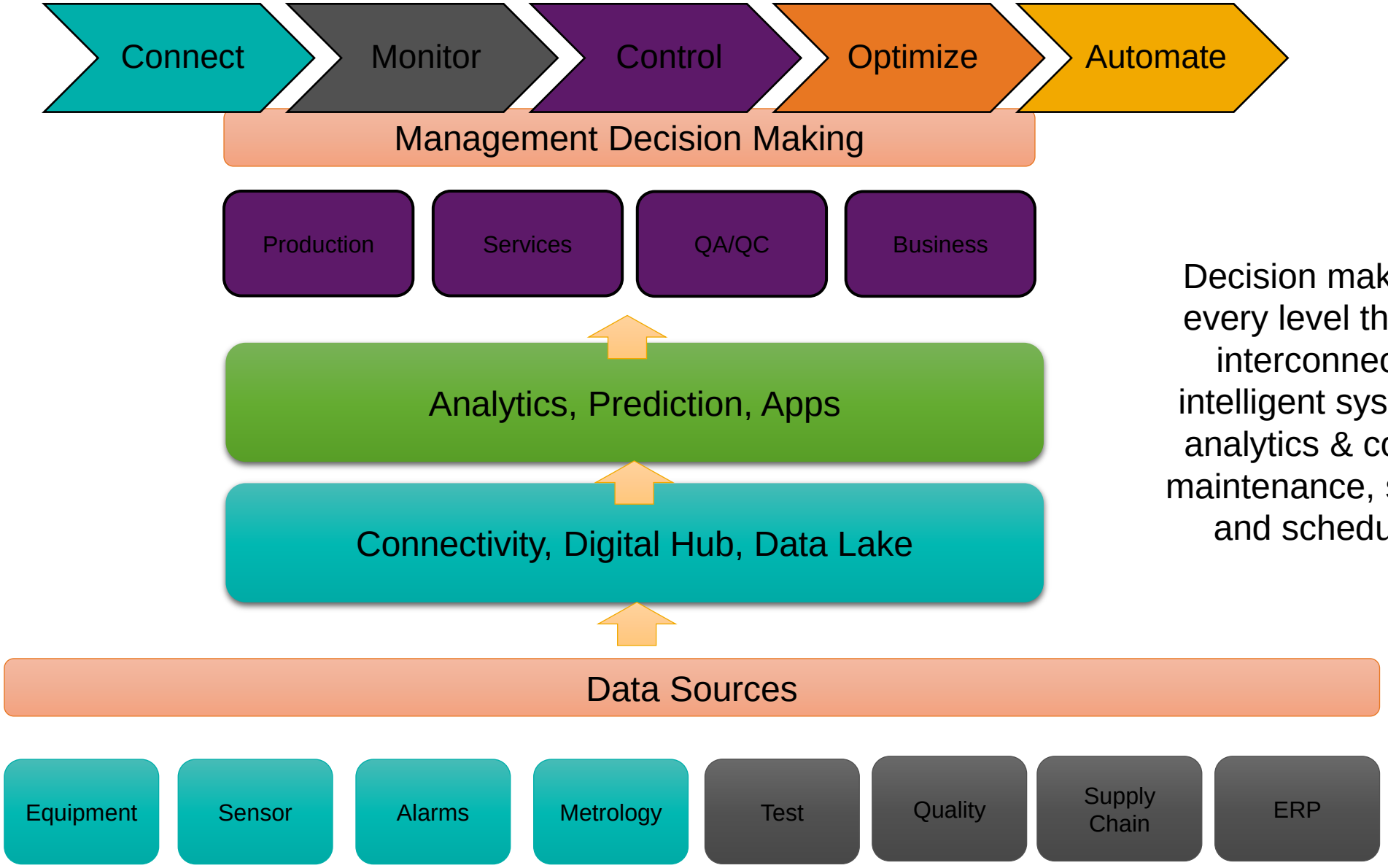
Supply Chain

Master Planning, Factory Planning, Capacity, Starts, Layout Simulation, Integrated Simulation, S &Op Planning

Equipment Control

Data Collection, Equipment Integration, Fault Detection, Equipment Productivity, Run-To-Run, Maintenance Management, Big Data

Digital Transformation (Industry 4.0)



Decision making at every level through interconnected intelligent system in analytics & control, maintenance, service and scheduling

Semi Manufacturing Generates Tremendous Data

Intelligent control requires sensor knowledge & analytics

300mm Single tool data per second

50KB per tool

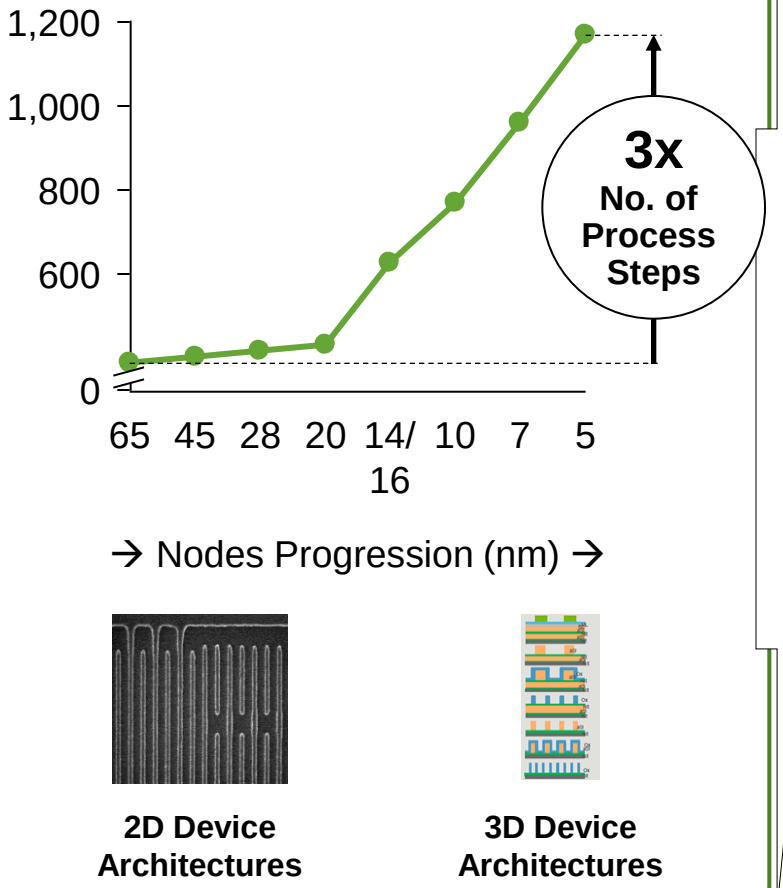
>500 tools per fab*

~1PB annual data per fab

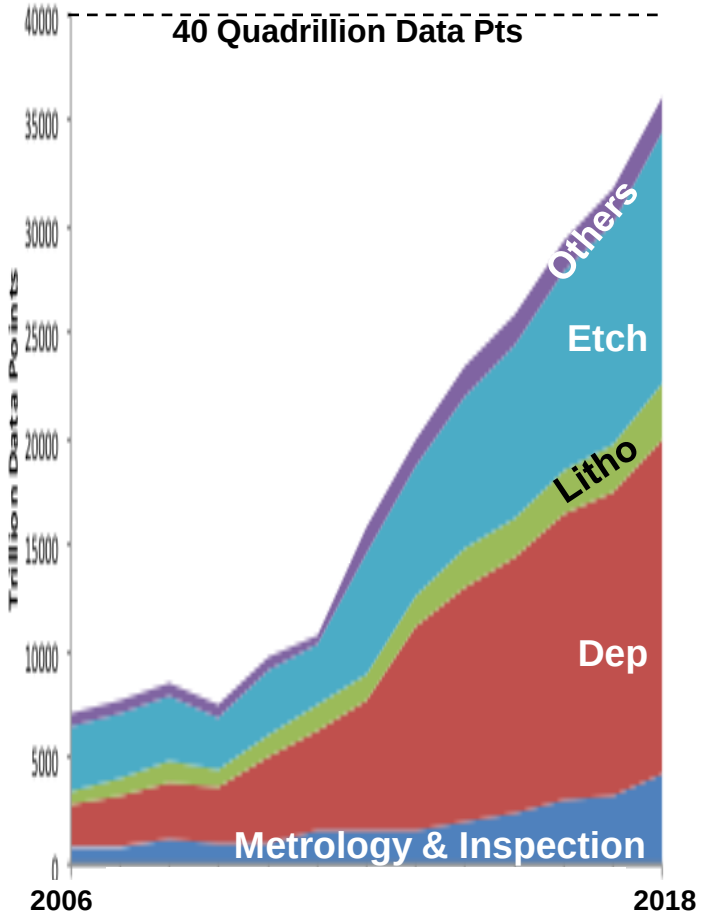
1000000000000000

* 30Kwspm fab

No. of Process Steps Grows 3x with Nodes



Quadrillions of Data Points by 2018



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Splunk Offline Log Analytics

Remote Monitoring

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Introduction to SmartFactory Health

- Health is a suite of software and services that monitor customer factory automation systems (hardware and software) to help maintain 99.999% uptime using the latest industry 4.0 principles:
  - Splunk Log Analytics: All the performance data are uploaded to Splunk through Secure FTP for detecting trends, anomalies and outliers using latest prediction algorithms

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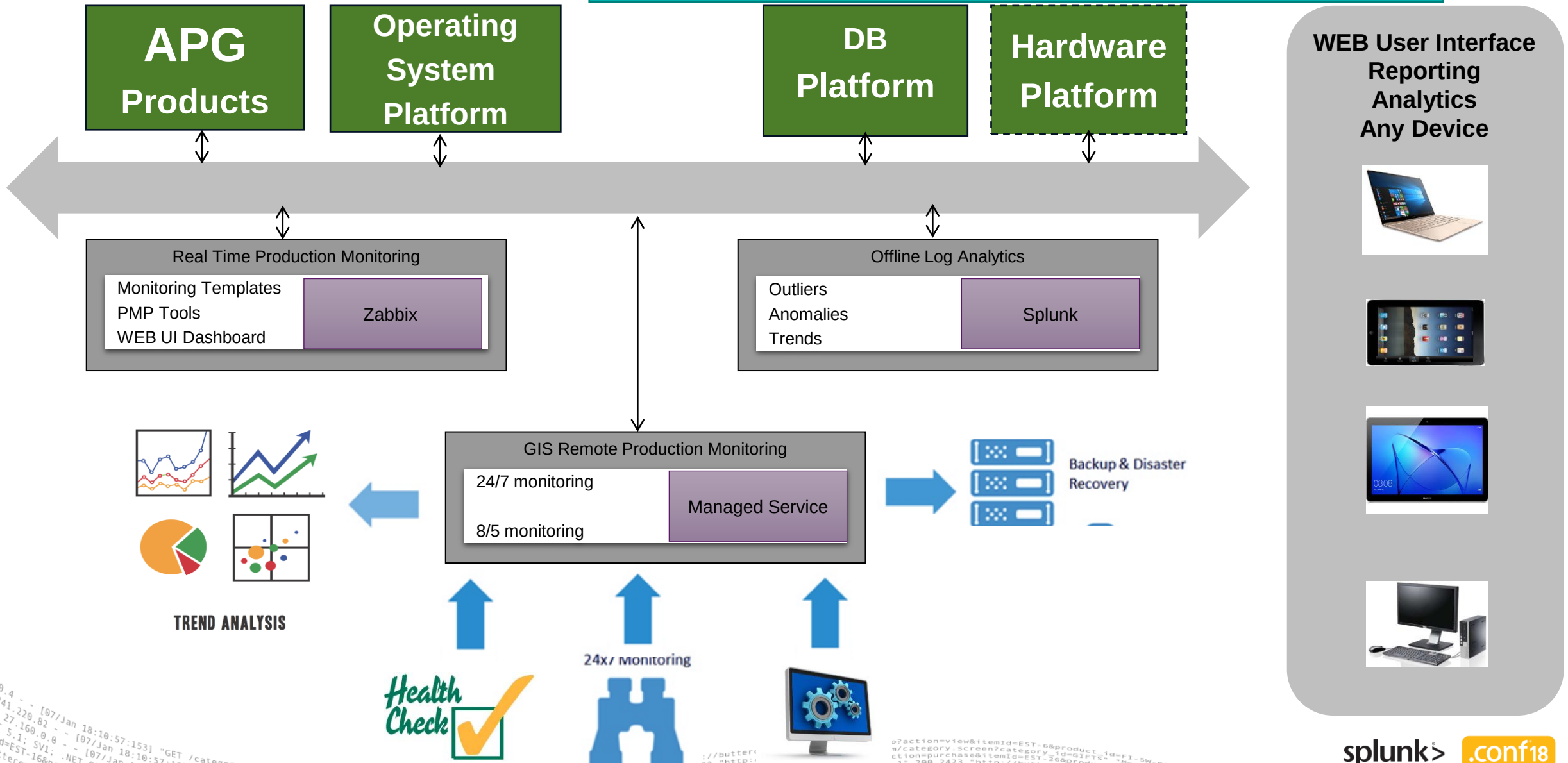
SmartFactory Health

Comprehensive monitoring solution that aligns with latest industry 4.0 principles



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Why Splunk offline Log Analytics

- **Monitor factory automation software** – make environment more productive and efficient by quickly troubleshooting issues on internal and customers' systems
  - **Manufacturing Execution Systems (MES), Computer Maintenance Management System (CMMS), Fault Detection, Dispatching , Scheduling**
  - **Windows and Linux OS**
  - **Oracle**
  - **Zabbix**
- **Without Splunk offline Log Analytics**:
  - Manual trouble shooting process which consists of Ftp'ing logs from operating systems, middleware applications and data bases.
  - Some API calls execute but never complete and that loop is not closed.
- **With Splunk offline Log Analytics:**
  - Proactive troubleshooting - automatically collecting and analyzing data quickly in order to anticipate problems before they affect the manufacturing environments.

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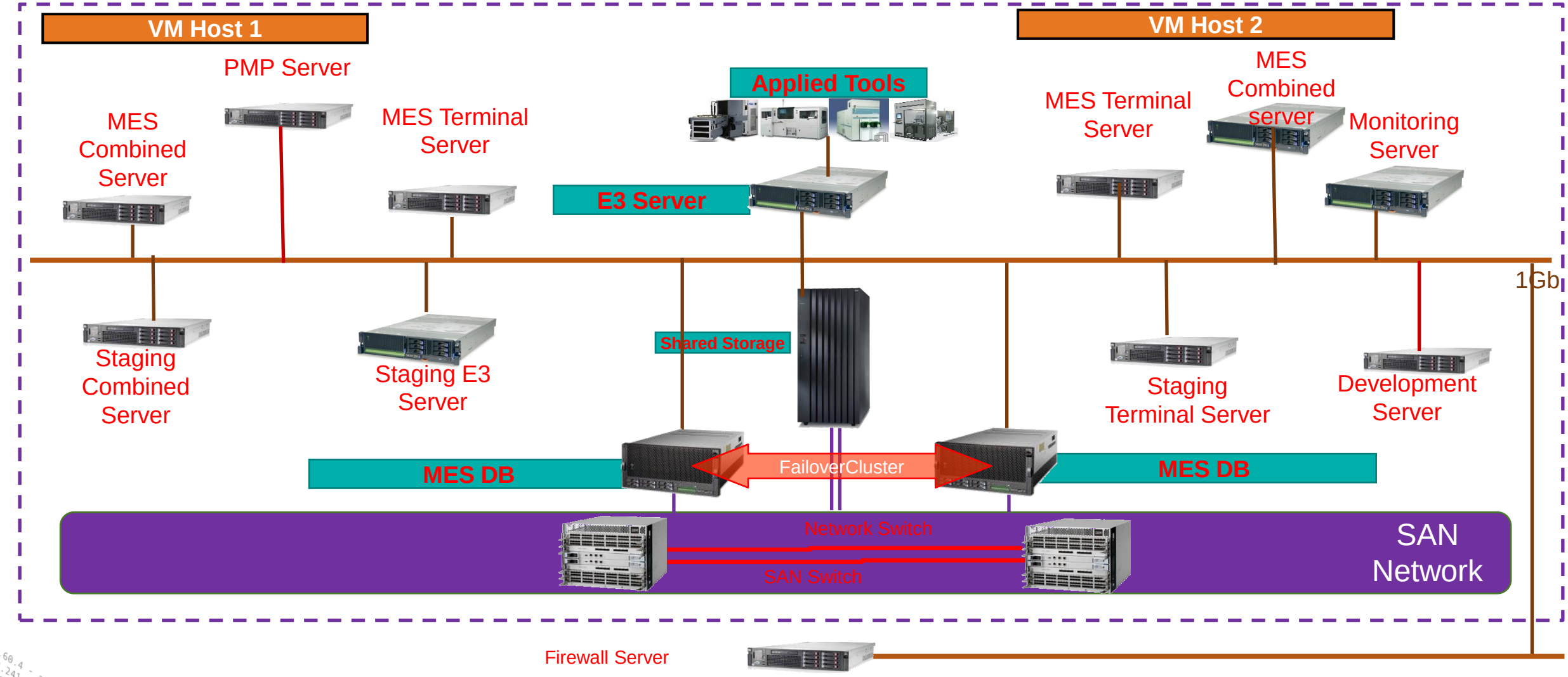
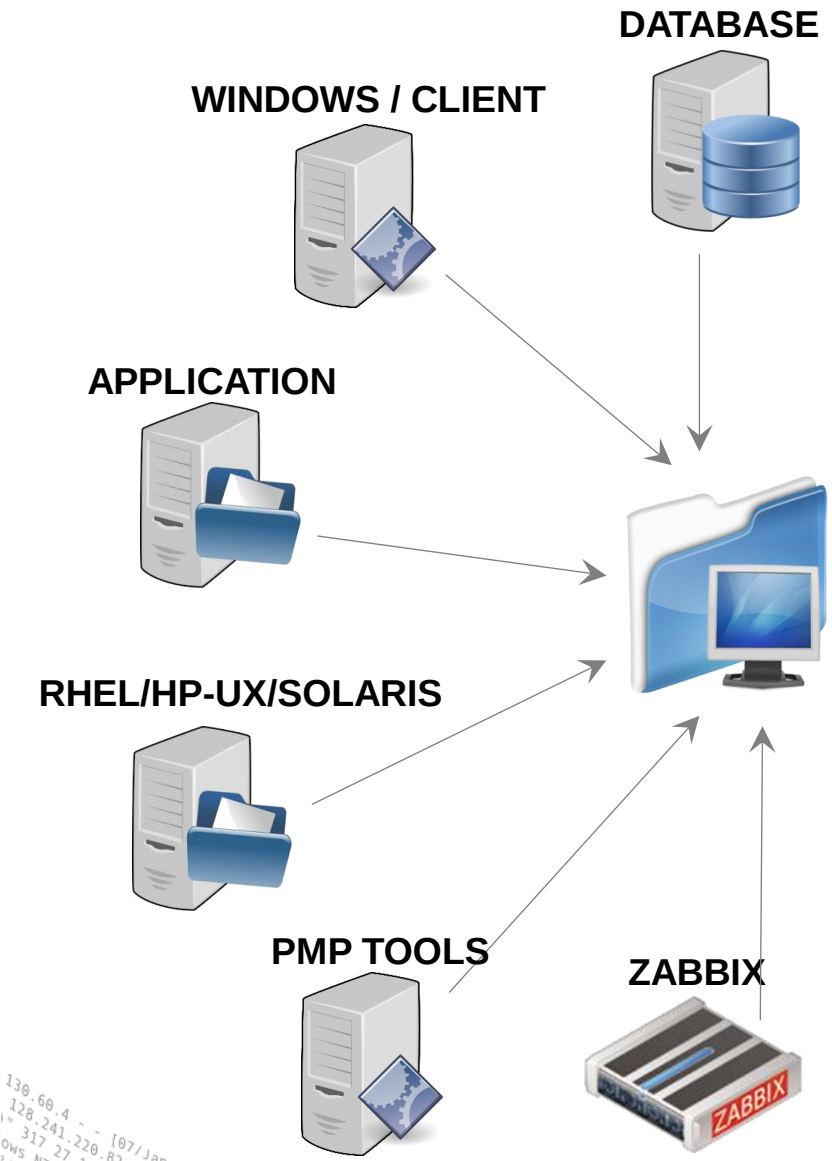
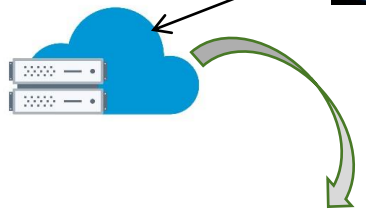
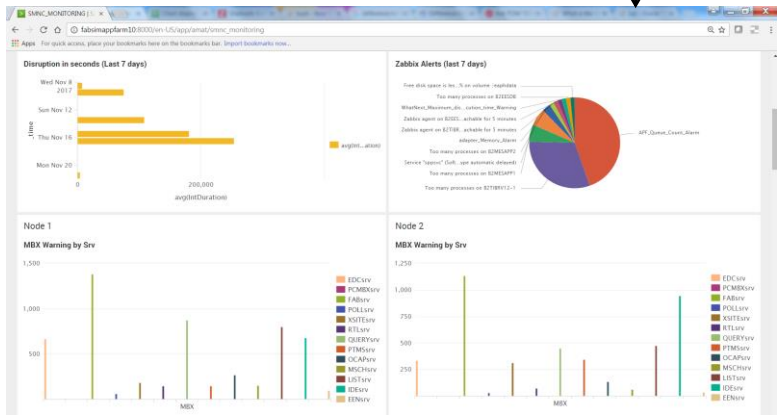
Typical Architecture running 24/7 (Production/Staging/Development Environment)



Log Analytics Architecture offline







Logs Collected for Analysis – Windows Event Logs, Oracle Alert Log, Statspack, AWR reports, Zabbix Problem Reports, Windows PS logs, SAR Output files, Performance logs from Application, Syslog, Application logs, RHEL/HP-UX/Solaris server logs, Perfmon files.

Secure FTP : Collected data is zipped and transferred to AMAT network through secure FTP

Splunk Server : High performance computing server in AMAT network that allows read access to Applied customers to visualize the factory performance and detect trends

Splunk Dashboard : allows you to monitor and better understand the data associated with machines and applications.

- Collected data is ingested into Splunk with indexes and provides real-time search, analytics, and reporting.
- Organize data patterns, diagnose potential problems, and application management and security.

Typical ingestion rate for low volume factory

Raw Logs -> summarized reports -> zipped for FTP -> unzipped for Splunk ingestion

Size of the raw logs from All servers in 24 hours 1GB

Size of the summarized logs from All servers in 24 hours 250MB

Logs ingested into Splunk [Growth of index after ingestion] 215M

681 files moved and ingested per day

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Log Ingestion

Different analytics performed to proactively detect performance issues

	Format	Analytics performed
Summary API Performance Report	CSV	Performance outliers, Performance Trends, Load Balancing
Summary Script Performance Report	CSV	Performance outliers, Performance Trends, Load Balancing
Detailed Synchronous Transaction Report	CSV	Performance outliers, Performance Trends, Load Balancing
Detailed Asynchronous Transaction Report	CSV	Performance outliers, Performance Trends, Load Balancing
Windows Application Event Log report	CSV	Asset management, Performance Outliers
Windows System Event Log Report	CSV	Asset management, Performance Outliers
Oracle Alert Log	Time series	Performance Outliers
Oracle Statspack Report	Text file	Oracle Wait Event Analysis , SQL Performance analysis
Listener Log	Time series	Performance Outliers
Psloggedon report	Text file	User Login Analysis
PSlog list report	Text file	Process CPU and memory outlier detection
Web UI log	Text file	Performance outliers, Performance Trends
Log Analyzer report	CSV	Asset management, Performance Outliers
Zabbix Problem Resolution report	CSV	Asset management, Performance Outliers
Windows Update Log	Text file	Performance Outliers

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Alert generation

Perform analytics during data ingestion

Title
Application Servers Application Event Load Balance (PRD)
Application Servers Application Event Load Balance (STG)

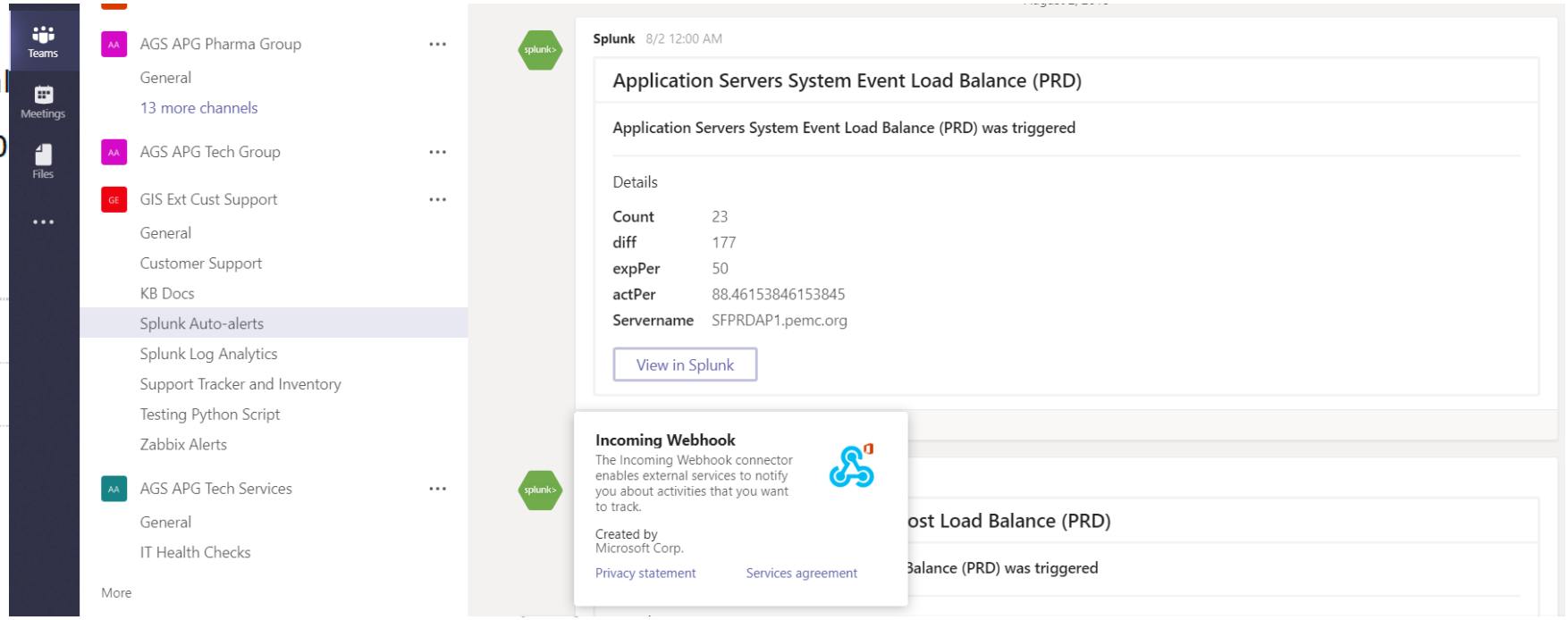
The alert condition for 'Terminal Servers System Event Load Balance (PRD)' was triggered as the number of System Event Errors in TS1 and TS2 are higher/lower than the acceptable load balance range (55-45)

Alert: Terminal Servers System Event Load Balance (PRD)

Trigger: Saved Search [Terminal

Trigger Time: 02:00:11 on July 31, 20

Servername	Count	expPer
SFPRDTS1.pemc.org	1	50
SFPRDTS2.pemc.org	2	50



YMS Servers Process Load Balance (PRD)

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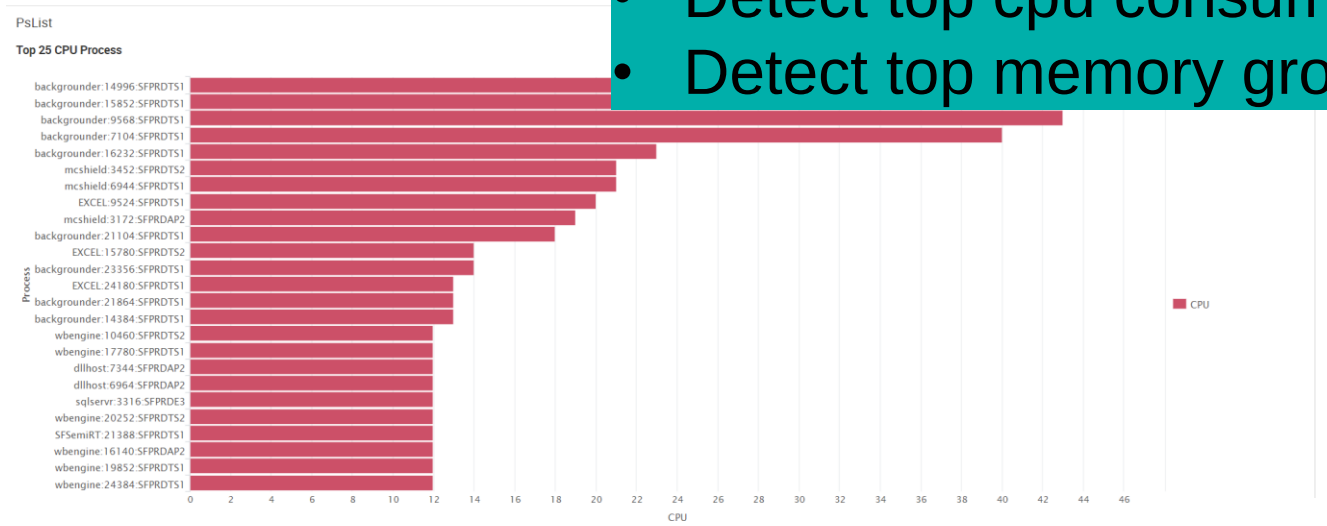
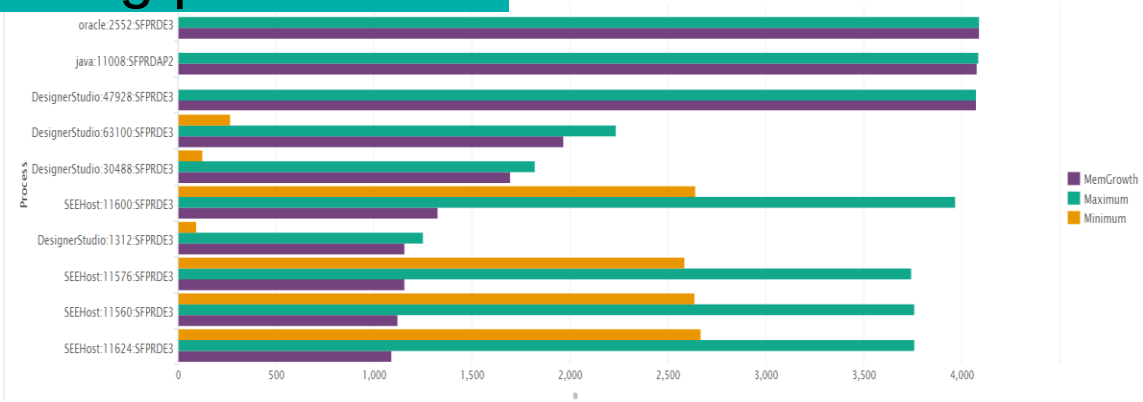
Optimize CPU and Memory utilization

Using pslist data

- Detect top cpu consuming process
- Detect top memory growing process



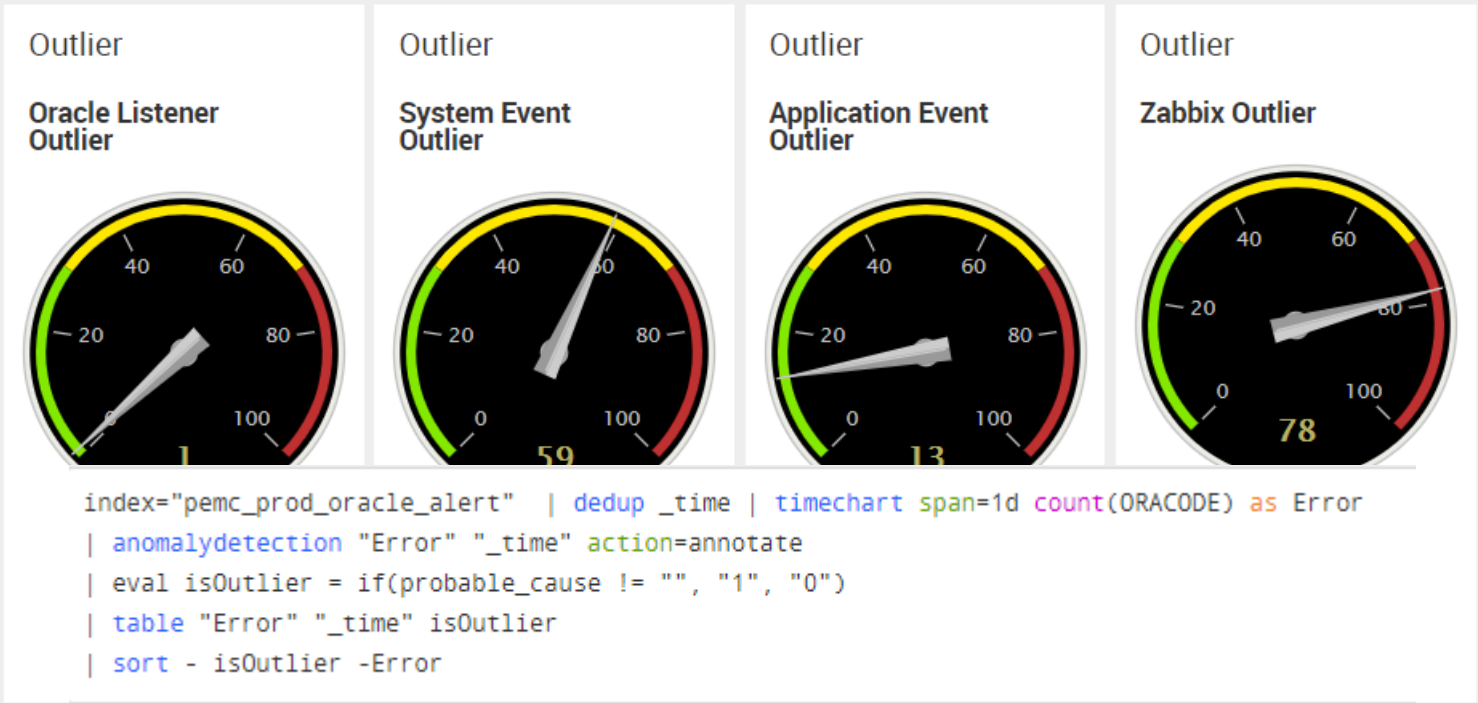



```
index="pemc_pslist" source="*PRD*" | rex field=_raw "(?<Name>\w*_\w*_\w*|\w*)\s*(?<PID>\d*)\s*(?<CPU>\d*)\s*(?<Thd>\d*)\s*(?<Hnd>\d*)\s*(?<Priv>\d*)\s*" | where Name !="Idle" | eval ProcessName=Name.":"
    .PID | rex field=source "Pslist_(?<Server>\w+)_\d*_\d*" | eval Process=ProcessName.":".Server | table Process  CPU | sort - CPU | dedup Process | head 25
```

```
index="pemc_pslist" source="*PRD*" | rex field=_raw "(?<Name>\w*_\w*_\w*|\w*)\s*(?<PID>\d*)\s*(?<CPU>\d*)\s*(?<Thd>\d*)\s*(?<Hnd>\d*)\s*(?<Priv>\d*)\s*" | where Name !="Idle" | eval ProcessName=Name.":"
    .PID | rex field=source "Pslist_(?<Server>\w+)_\d*_\d*" | eval Process=ProcessName.":".Server | stats min(Priv) as Minimum max(Priv) as Maximum by Process | eval MemGrowth=(Maximum-Minimum) | eval
    MemGrowth=round((MemGrowth/1024),2), Maximum=round((Maximum/1024),2) , Minimum=round((Minimum/1024),2) | table Process MemGrowth  Maximum Minimum | sort - MemGrowth | head 10
```

Detect Outliers

Oracle Alert Log, Listener Log, System Event, Application Event, Zabbix problems




```
index="pemc_prod_oracle_alert"  | dedup _time | timechart span=1d count(ORACODE) as Error
| anomalydetection "Error" "_time" action=annotate
| eval isOutlier = if(probable_cause != "", "1", "0")
| table "Error" "_time" isOutlier
| sort - isOutlier -Error
```

Detect outliers from time series data

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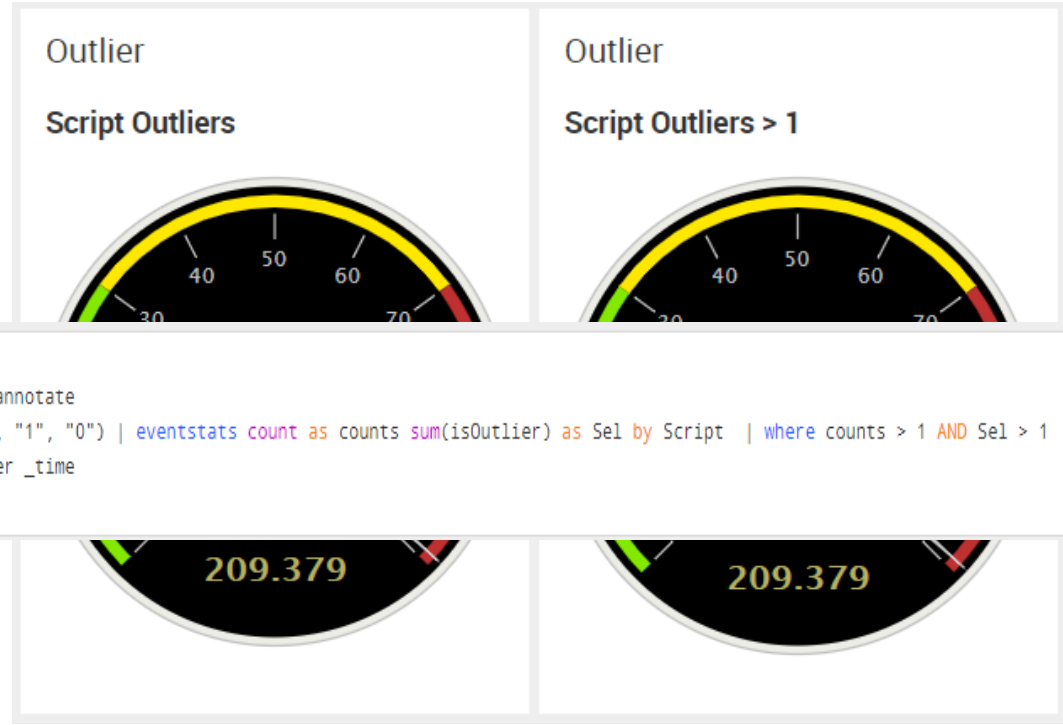
Detect Transaction Outliers

Using transaction performance data




```
index="pemc_prod_fab300_script"
| anomalydetection "Mean" "Script" action=annotate
| eval isOutlier = if(probable_cause != "", "1", "0") | eventstats count as counts sum(isOutlier) as Sel by Script  | where counts > 1 AND Sel > 1
| table Mean Script probable_cause isOutlier _time
| sort -isOutlier -Mean
```

Script causing performance issue on more than 1 execution

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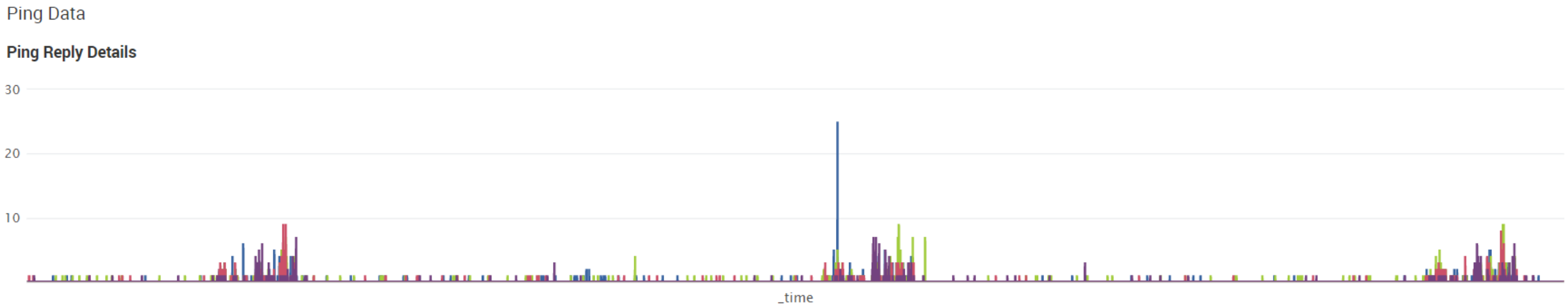
Network health issue detection

Using the ping data



Detect the network health using the ping response time on each server node

Predict Trends in SQL Performance

Oracle Stats pack or AWR data provide detailed report on SQL Performance (every 10 minutes)

Top SQL by Gets

BufferGets	Executions	GetsPerExec	Total	CPUTime	ElapsedTime	OldHashValue	Module_SQLtxt
1768021	18	98,223.4	77.4	6.36	7.64	3910735843	Module: w3wp.exe
1424369	15	94,957.9	41.0	4.09	6.19	2085294652	Module: w3wp.exe
1142890	12	95,240.8	54.2	4.72	5.13	2813490068	Module: w3wp.exe
837503	9	93,055.9	57.8	2.48	3.74	2921702126	Module: w3wp.exe
698072	7	99,724.6	45.8	1.89	3.00	3334228419	Module: w3wp.exe
571934	6	95,322.3	25.2	2.19	2.61	4292665490	Module: w3wp.exe
547641	6	91,273.5	38.8	1.19	2.38	3201563124	Module: w3wp.exe
362550							
195006							
190706							
119044							
95717							
93313							
20952							

```
index=statspack  | rex "(?s)SQL ordered by Gets\s*\w*\W+\w*\W+\s*\w*\W+\w*\s*\w*\W+\s*\d*-
\d*\s*\W*\s*\w*\s\w*\s\w*\s\w*\W\s*\d*\s*\w*\s\w*\s\w*\W\s*\d*\,?\d*\,?\d*\s*\W*\s*\w*\s\
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\w\W\s*\w*\s\W\w\W\s*\w*\s\w*\s*\W*(?<BufferGets>\d*\,?\d*\,?\d*)\s*(?<Executions>\d*\,?\d*)
\s\s?\s?\s?\s?\s?\s?\s?\s?\s?\s?(?<GetsPerExec>\d*\,?\d*\,?\d*.\d*)\s*(?<Total>(\d*.?\d*)(\W*))\s*(?
<CPUTime>\d*.\d*)\s*(?<ElapsedTime>\d*\.?\d*)\s*(?<OldHashValue>\d*)\s*(?<Module_SQLtxt>.+?\n
)\s+\s+\s+\s+\s+\s*"  | where OldHashValue=1516109899  | rex mode=sed field=GetsPerExec "s/ //g" |
rex mode=sed field=GetsPerExec "s/,//g" | timechart span=15m values(GetsPerExec) as GetsPerExec  |
predict "GetsPerExec" algorithm=LLP5 future_timespan=99
```

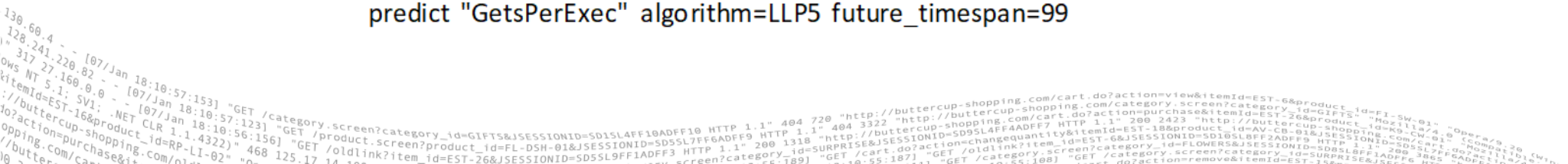

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SPL Challenges & Optimization

- Issue Description
  - SPL was taking almost 430 seconds for an index with almost 3 million events.
  - The SPL was straightforward and had no complicated filters.
- Fixes suggested by supported team
  - changing/removing the filters
  - Move panel to a separate dashboard
- Support team brought in Splunk architect to help
  - SPL was built into a data source with all the filters prebuilt in the data source.
- Results
  - Reduced the total time taken by the panel by more than 50%.
  - Panel moved back to the original dashboard with 60 panels
  - No further performance issues even when the search runs along with 60 other searches.

SPL Performance Issue (cont..)

- Converting to data source
  - 24 hours – Improved from 7 seconds to 1.5 seconds
  - 30 Days – Improved from 70 seconds to 30 seconds
  - All Time – improved from 430 seconds to 213 seconds

- Number of events for the timeframe
  - 24 hours - **636,837**
  - 30 Days - **13,976,231**
  - All Time - **27,793,007**

Splunk Data Snippets

Total number of dashboards	5
Average number of panels per dashboard	100
Total number of Index	300
Total number of Source types	150
Average size of files ingested daily	5G

Expected to scale
up by 5X times
within next 2 years

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How Splunk helps

Remote monitoring team proactively has detected more than 100 issues

- Any unscheduled down causes business loss
- 1 hour of unscheduled down
  - Low Volume FAB - $10K
  - Medium Volume FAB - $100K
  - High Volume FAB - $1M

Thank You & Questions

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