Public Safety Broadband Demonstration - Broomfield, CO **March 7, 2012**

Service Assurance – Performance Management Challenges

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Introduction to AIRCOM International

AIRCOM is a leading independent provider of end-to-end software products and consulting services designed to plan, manage and optimise mobile networks

- **Global market leader in mobile Network Planning, Optimisation and Performance Management (PM) solutions**
- **Recognized and Trusted Industry Expert across all major radio and core technologies including GSM, CDMA, UMTS, WiMAX and LTE**
- **350+ mobile operator customers in 135+ countries including product and service deployments with all of the top 20 largest global mobile operators**

Software

Core Capabilities

- **Market Leading Radio Planning Tool – AIRCOM ASSET**
- **Highly scalable, flexible Mobile Network Performance Management – AIRCOM OPTIMA**
- **Integrated RAN/Backhaul Planning and Optimisation/Dimensioning capabilities**
- **Multi-Technology / Multi-Vendor tools, already Interfacing to all leading equipment**

Consulting Services

Core Capabilities

- **Strategy and Technology Planning**
- **Network Design and Planning**
- **Spectrum Re-farming Solutions**
- **Vendor Management**
- **Roll-out Management**
- **Optimisation and Audit Services**
- **Network operations outsourcing**

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AIRCOM Trusted Advisor to Operators for LTE/SON

- **AIRCOM selected for Technology Evaluation and during first LTE deployments**
- **Executed LTE Field Trials and facilitated NEP supplier evaluation for Tier 1 USA mobile network operator (MNO)**
- **Performed interworking study for USA Tier 2 LTE network**
- **LTE versions of our software tools are commercially deployed at over 20 MNOs**
- **Our consultancy services have been used to deliver LTE solutions across 3 continents NA, EU & APAC**

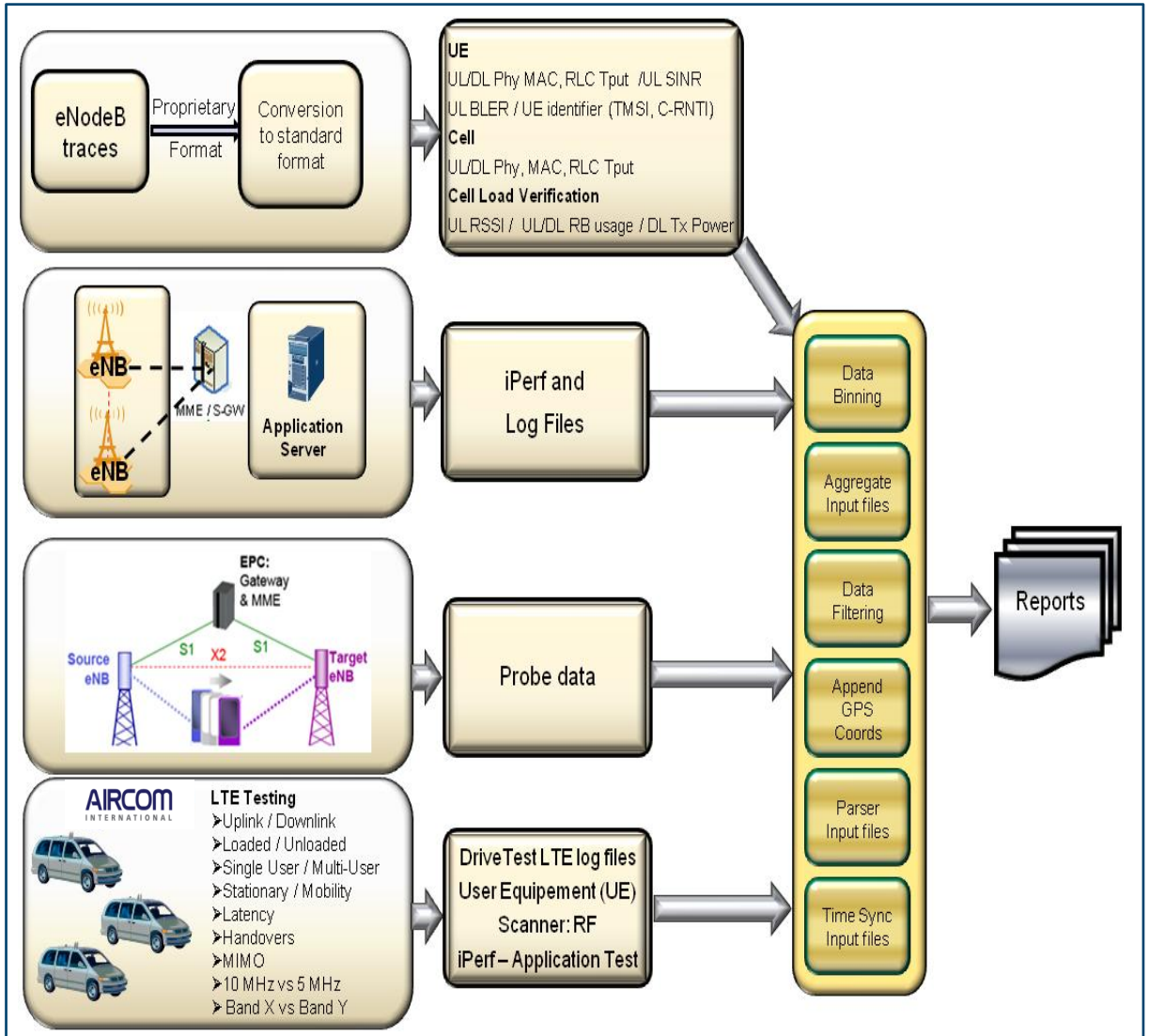

Figure: AIRCOM Field Trial Evaluation Framework used for Tier 1 USA MNO

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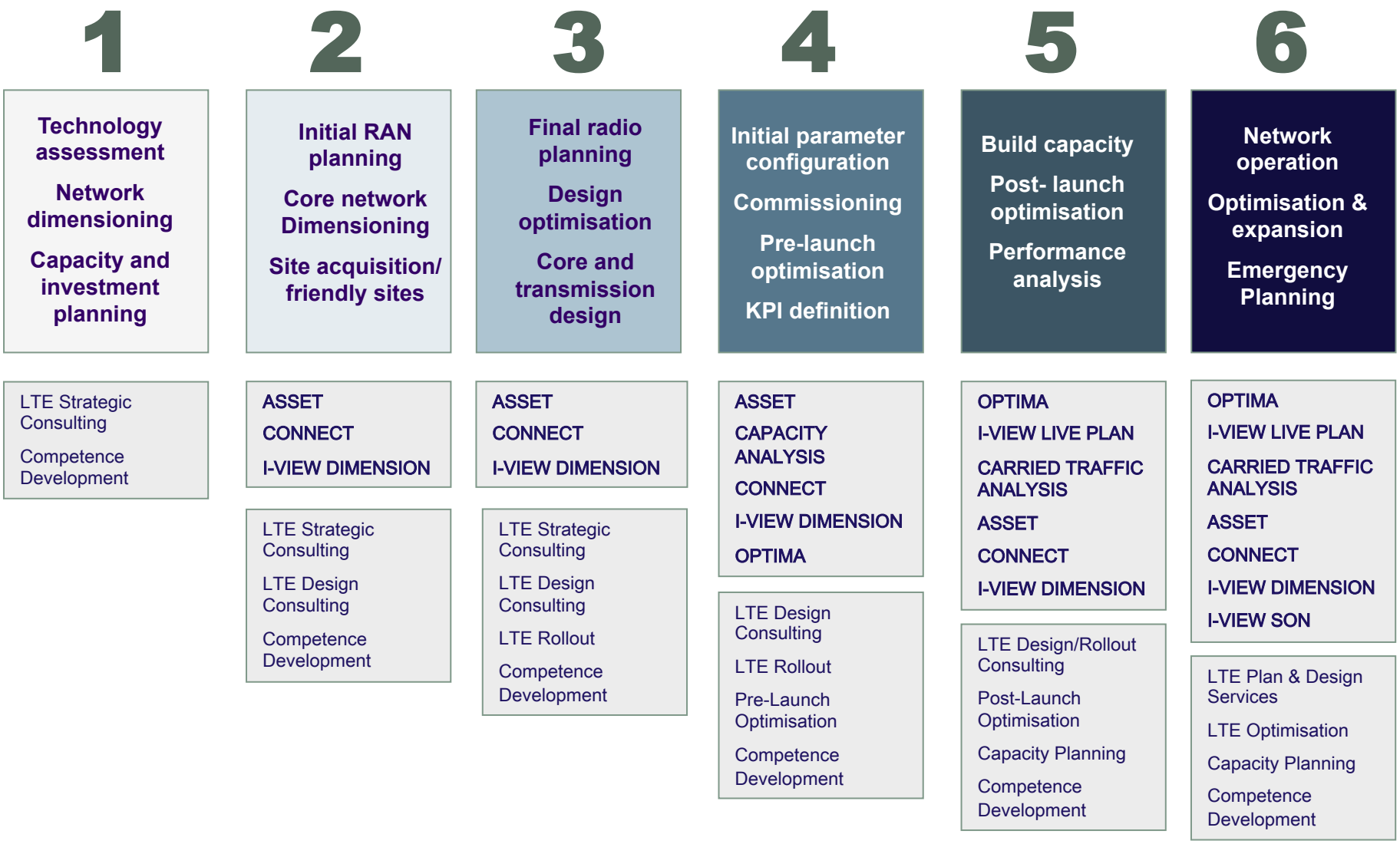
LTE Technology Lifecycle



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PSCR Service Assurance
Harmonized Performance Management (PM)

Why Harmonize Performance Management (PM)?

- It's critical that all First Responder organisations get the communications services they need when they need them
- Harmonized PM means the First Responder Network Authority (FirstNet) can centrally monitor and assess communications services for all public safety agencies using common metrics and processes irrespective of network vendor used or geographical region
- Correlation of data from many sources throughout the communications ecosystem is required to evaluate the true quality of experience (QoE), bringing together the application layer, wireless network and transport infrastructure including both the user and control plane (signalling) information
- Traditional Performance Management (PM) systems have struggled to meet the demands of UMTS when monitoring a USA nationwide network. LTE is in it's infancy but has the same challenges such as per eNodeB PM files creating a processing challenge, flat architecture disconnecting QoE from resource performance etc....
- Public Safety Networks require best in class support systems, that perform under all conditions and provide common harmonized information where and when it's needed

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Performance Management (PM) Core Requirements

Data Analytics

A user needs to see a high level 'monitoring view' but also be able to drill into the details for troubleshooting

To be confident with the analysis a user needs to be sure the data availability, that it's integrity is high, and is made available in near real-time

End-to-End

As interdependence between network domains increases it is no longer feasible to analyse the network components in isolation

Tools need to provide correlation and end-to-end views to avoid significant manual work during troubleshooting and reporting

Multi-Vendor

- With typically 15 or more vendors in a network managing all the vendor specific tools is costly and time consuming
- Having multiple tools makes it difficult to get an aligned view of performance across vendors without significant manual work

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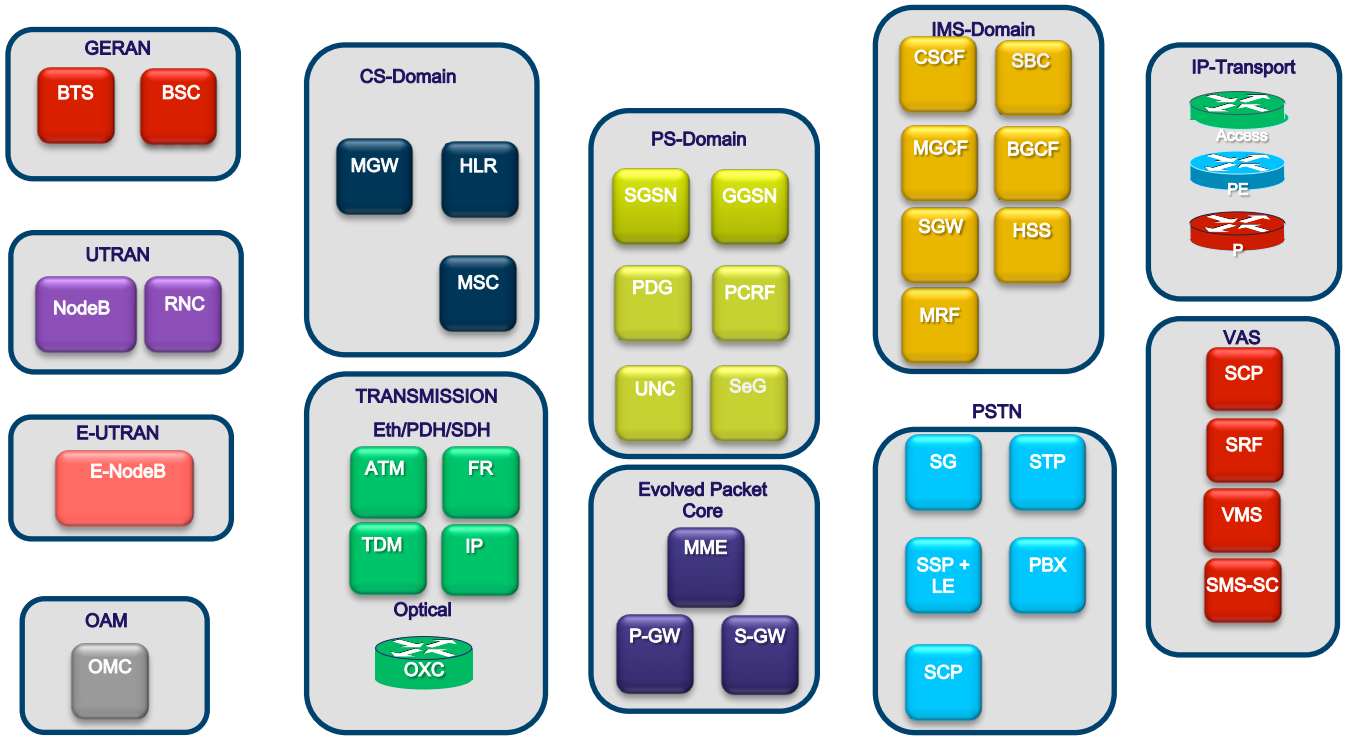
One central PM repository for all Domains

- **Single platform for Mobile RAN, Mobile Core, IP, Transmission and Fixed network and Value Added Services (VAS) domains.**



- **Integration with Planning tools, Business Intelligence tools, Fault Management systems, Service Quality Management systems, Customer Experience systems, etc.**

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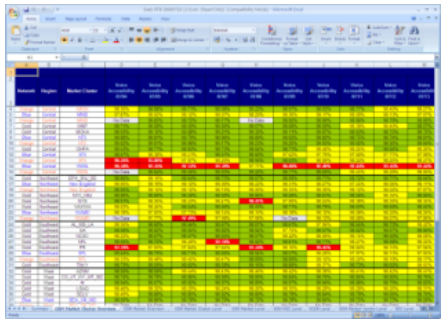
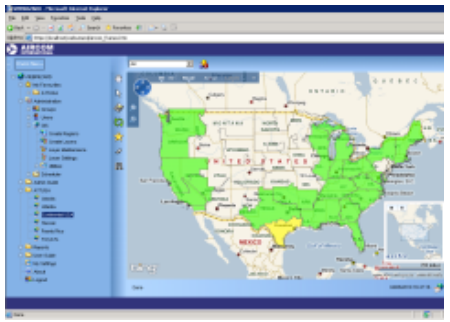
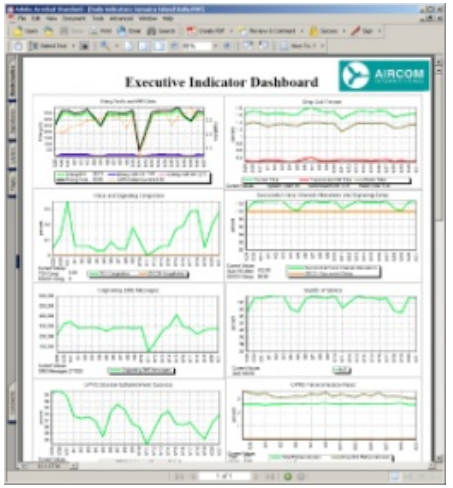
Case Study - World's Largest Centralized PM System

- After extensive trials, scalability lab testing with Sun, HP and Teradata and evaluation by the operator of all PM systems on the market AIRCOM OPTIMA was selected as the best in class PM Tool by a USA Tier 1
- Requirement was to have a single centralised data warehouse capable of replacing the MNOs existing commercial grade PM and in-house PM systems.
- Over 10 regional databases and a nationwide system were replaced by AIRCOM OPTIMA which has now become the largest centralised PM system for wireless in the world:
  - Loading near real-time data from over 350,000 GSM, UMTS and LTE cells
  - Supporting over 2000 users
  - Storage >0.5 PetaBytes (500 TeraBytes)
  - Now supporting over 65 different interfaces types providing an end-to-end view
- High availability system required for Performance Management System
  - Highly robust system resilient to single point and multiple system failure
  - Rolling interface upgrade support, zero outage requirement for Vendor Interface upgrades
  - Oracle Real Application Clusters (RAC) used to enable minimal outages for Database and Operation System upgrades.
  - Fast recovery from Vendor OSS outages with extreme loading performance







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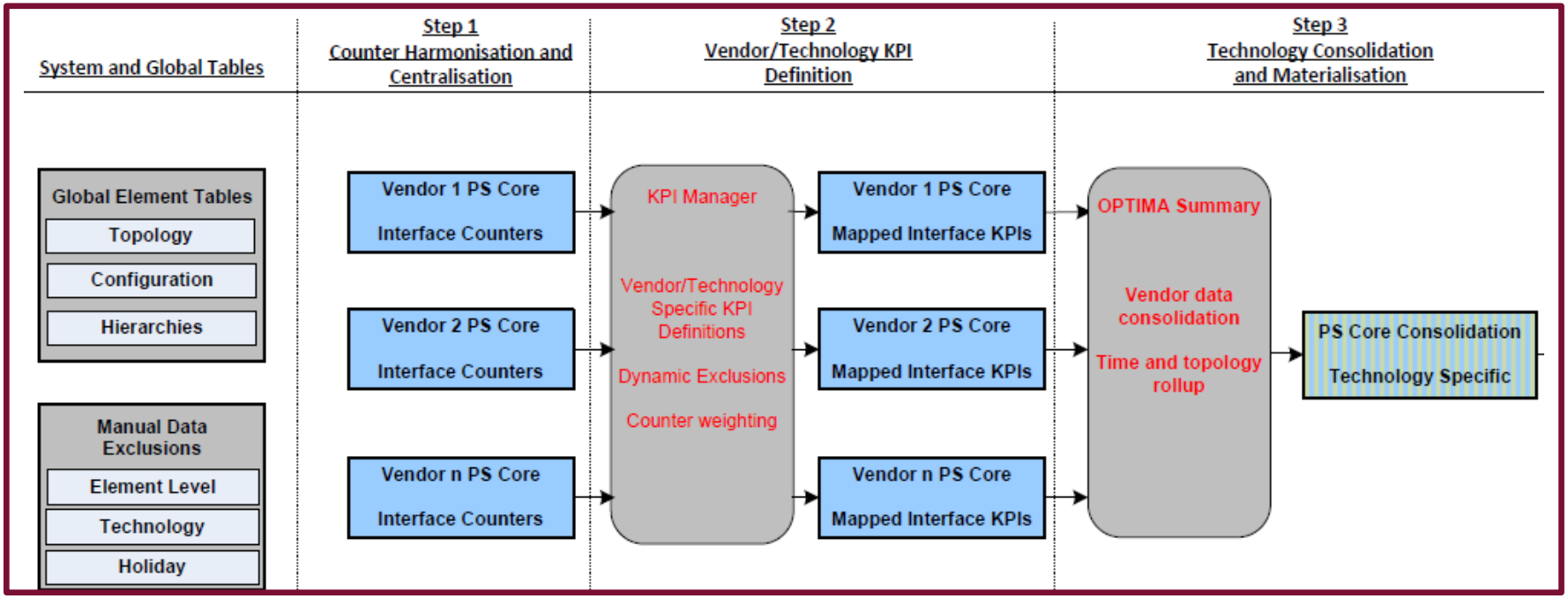
PSCR Service Assurance
Key Performance Indicators (KPIs)

KPIs – Multi-vendor Harmonisation

- Harmonized common KPIs mapped from each vendor (software release dependent)
- Common set of KPIs used for Reporting, Alarming and Investigation enable complex analysis and reporting
- Aggregated by Topology and Market (with exclusion tables) to provide higher level reporting



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A selection of AIRCOM's vendor coverage

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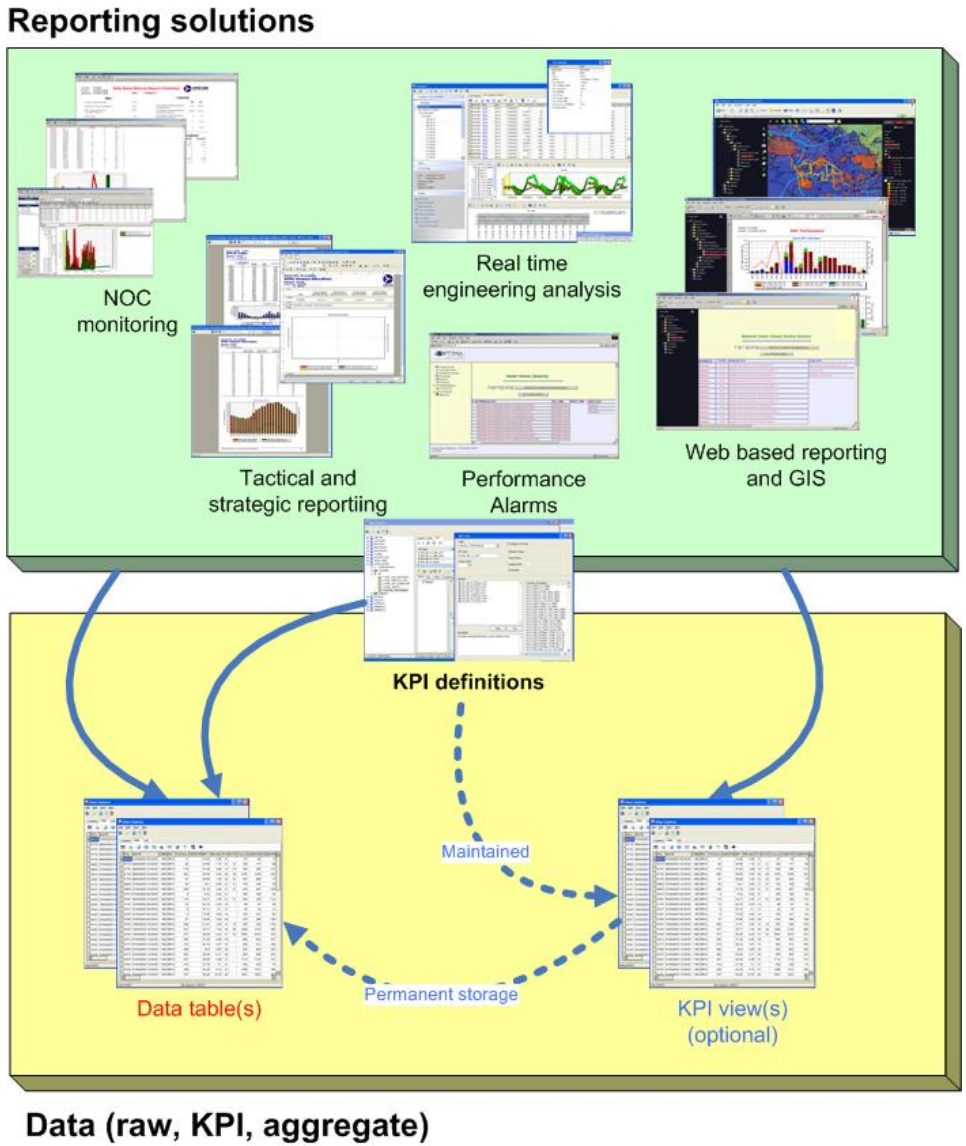
PM System KPI architecture



- Centrally stored KPI definitions can be used by each function of the PM
- Reporting solutions can:
  - Directly access raw and aggregate summary data
  - Same KPIs definitions used on raw and summary data (element or time aggregation)
  - Directly query KPI views, maintained by the same KPI definitions
  - KPI views can be used with the AIRCOM OPTIMA summary to create permanent storage

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Example LTE PM KPI Areas

KPI Classes	eUTRAN	MME	S-GW / P-GW
• Accessibility • Retainability • Availability • Mobility • Network Usage • Integrity • Subscribers • Network Resources • GTP Measurement • Session Management	**KPI Areas** • Paging Performance • Network Access • RRC Conn Establish • S1 Sig Establish • ERAB Establish • ERAB Modification • CSSR • RRC Call Drops • VOIP Call Drops • Total Call Drops • Unavailability • UL Congestion • DL Congestion • CPU Usage • eNodeB Power • Users count • Total Throughput • IP Latency • HO (LTE <-> UTRAN) • HO (LTE <-> GERAN) • HO Inter Freq	**KPI Areas** • Attachments • Detachments • Tracking Area Updates • PS Paging • Intra MME HO's • Inter Source MME HO's • Inter Target MME HO's • X2 HO's • Subscriber Statistics • S1 Service Request • EPS Dedicated Bearer Activation • EPS Dedicated Bearer deactivation • EPS Dedicated Bearer modification • CPU Usage • IP interface stats	**KPI Areas** • Authentication Transaction • Accounting Transaction • PDP Context Activation • PDP Context Deactivation • Dedicated Bearer Creation • Bearer Deletion • Bearer Update • APN Throughput • EPC Buffering • GTP Stats • Credit Control • Re-authorisation • CPU Usage • Memory Usage • IP Pool Usage • BMA Load Stats • Quota Mgr Load Stats • Interface Stats • Data Volume • Subscriber Stats

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Example Nationwide Overview (Rollup)

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National Report - Weekly

Level NATIONAL
Date December 19, 2011
Technology LTE
Vendor ALL

	Deployment				Accessibility (%)		Retainability (%)		Throughput				Paging (%)	Mobility (%)
MARKET	LTE Roll-out completion	LTE Sites Shared	Vendor	# eNodeBs	RAN	Core	eRAB Ret. Rate	TAU Success Rate	Average DL Throughput [Mbps]	Average UL Throughput [Mbps]	Average DL Volume Per Cell [GB]	Average UL Volume Per Cell [GB]	MME Paging SR	HOSR
Market 1	53%	27%	OEM 1	644	98.8	96.1	94.1	96.8	11.26	3.75	111	11	96.8	98.9
Market 2	54%	27%	OEM 2	475	95.8	97.7	99.0	96.6	22.79	7.60	6	44	99.5	98.9
Market 3	62%	31%	OEM 4	821	96.0	99.0	96.1	98.0	30.62	10.21	221	247	98.5	96.9
Market 4	94%	47%	OEM 3	503	99.9	98.9	96.7	99.6	11.91	3.97	400	78	99.2	99.9
Market 5	57%	29%	OEM 1	886	94.1	98.2	95.9	95.8	22.83	7.61	338	279	99.2	99.9
Market 6	70%	35%	OEM 2	641	98.0	98.4	97.7	96.8	18.89	6.30	285	98	99.7	96.8
Market 7	95%	48%	OEM 4	673	98.6	95.3	94.1	94.2	4.12	1.37	10	117	96.5	99.2
Market 8	78%	39%	OEM 3	806	95.8	96.3	96.0	98.3	13.23	4.41	683	74	99.2	96.5
Market 9	75%	38%	OEM 1	399	100.0	99.1	94.6	96.2	24.03	8.01	301	15	96.6	99.4
Market 10	78%	39%	OEM 2	937	99.5	94.4	96.8	94.6	31.84	10.61	542	180	96.1	97.9
Market 11	66%	33%	OEM 4	1,186	95.4	96.5	96.4	96.1	14.04	4.68	671	80	99.2	98.8
Market 12	57%	28%	OEM 3	632	98.3	99.6	95.4	97.3	7.27	2.42	147	134	98.1	99.9
Market 13	74%	37%	OEM 1	412	94.9	94.5	96.2	98.6	15.61	5.20	285	66	99.3	97.5
Market 14	67%	33%	OEM 2	447	94.0	96.9	94.8	98.4	31.03	10.34	321	56	97.5	98.5
Market 15	95%	47%	OEM 4	463	98.0	97.2	95.9	95.1	25.43	8.48	156	24	97.7	98.3
Market 16	95%	48%	OEM 3	1,264	98.6	95.6	98.0	97.6	20.44	6.81	254	331	98.7	96.8
Market 17	61%	31%	OEM 1	601	95.6	97.9	97.7	95.3	24.65	8.22	103	46	99.0	99.0
Market 18	60%	30%	OEM 2	1,154	96.2	96.7	99.1	95.3	29.46	9.82	695	91	96.6	97.8
Market 19	58%	29%	OEM 4	1,175	94.2	94.4	95.5	95.7	30.38	10.13	438	77	96.3	98.8
Market 20	76%	38%	OEM 3	535	97.9	95.7	99.6	98.6	32.90	10.97	256	149	96.1	98.1

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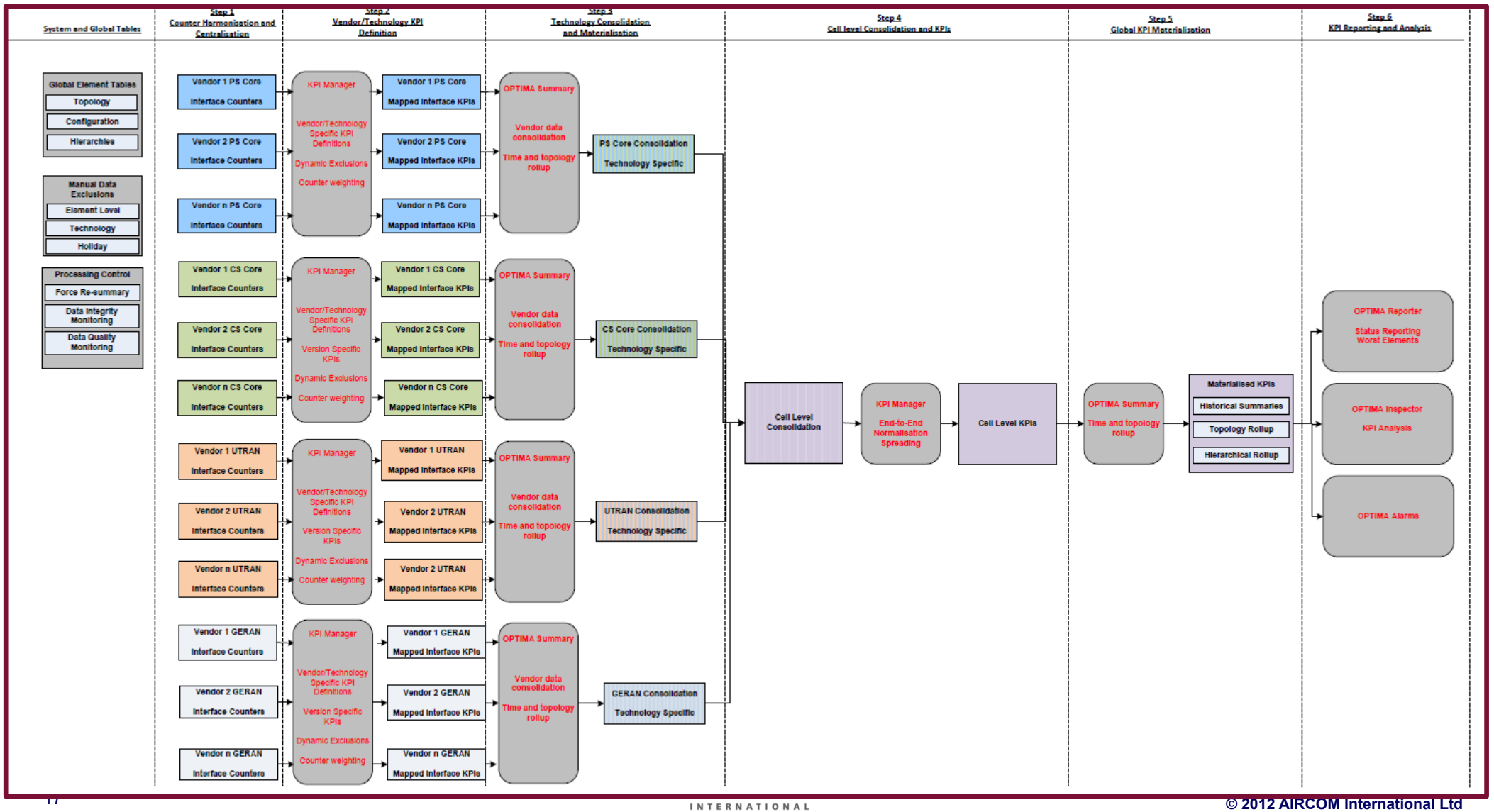
PSCR Service Assurance
End to End KPI Consolidation

KPIs – Consolidation to give End-to-End Perspective

- Combining and weighting KPIs to normalise and aggregate Radio Metrics with transport, core and content metrics can build an End to End metric
- End-to-end KPIs give an overall service level view



E2E KPI – Supplementing with Probe Data Sources

PM data can be supplemented with Probe data for further analysis to show:

- Volume of traffic traversing the network per service
- Additional KPIs: Packet size, Peak Packet Rate, mean to peak ratio
- Proportionate traffic breakdown into each PSCR service by device type, location etc….
- Throughput breakdown by service type vs time
- Round-Trip Time, Delay, Jitter, Packet Loss Etc…

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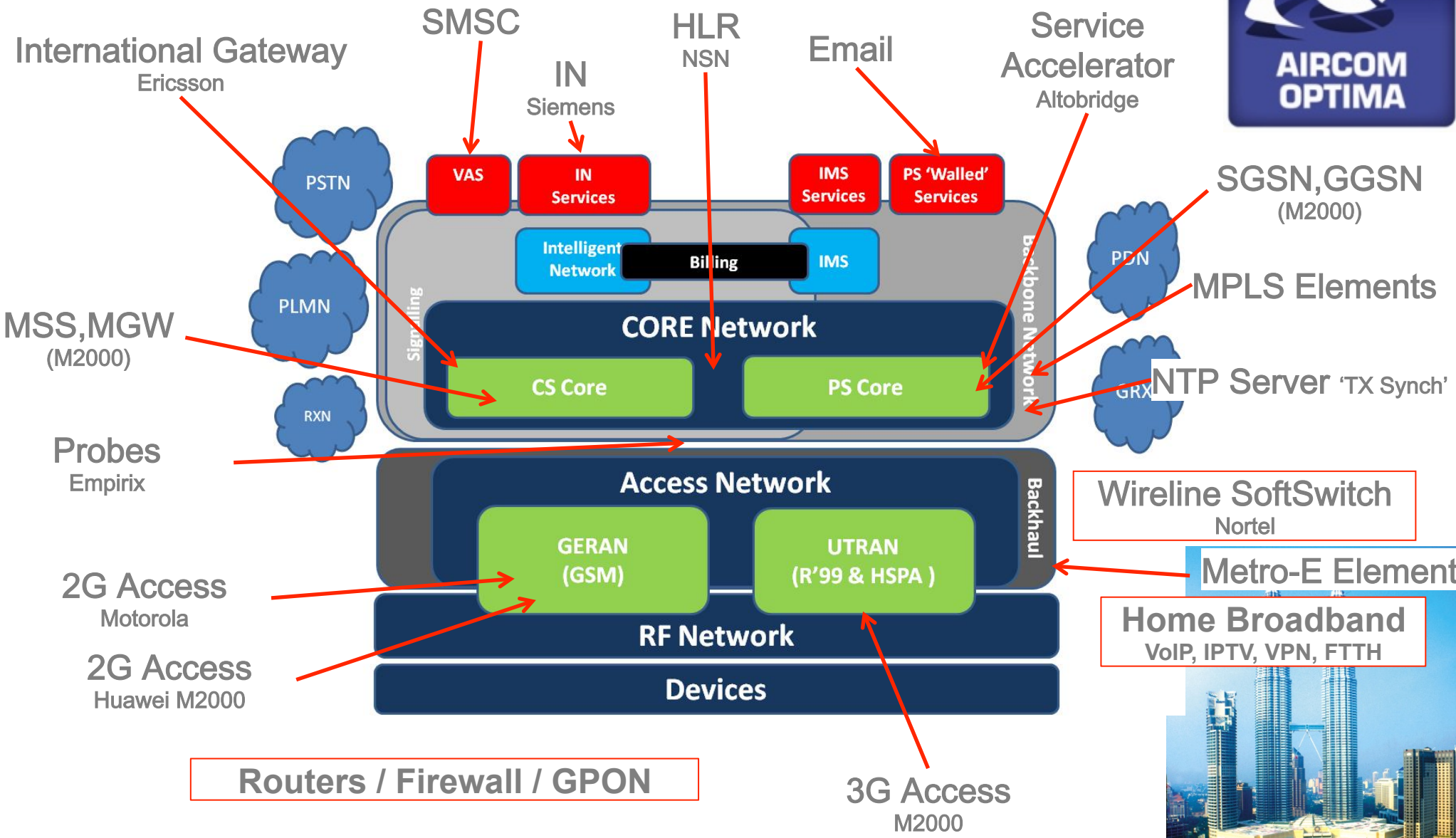
Case Study – E2E Performance Management



Case Study – Core IP Backbone Audit (E2E)

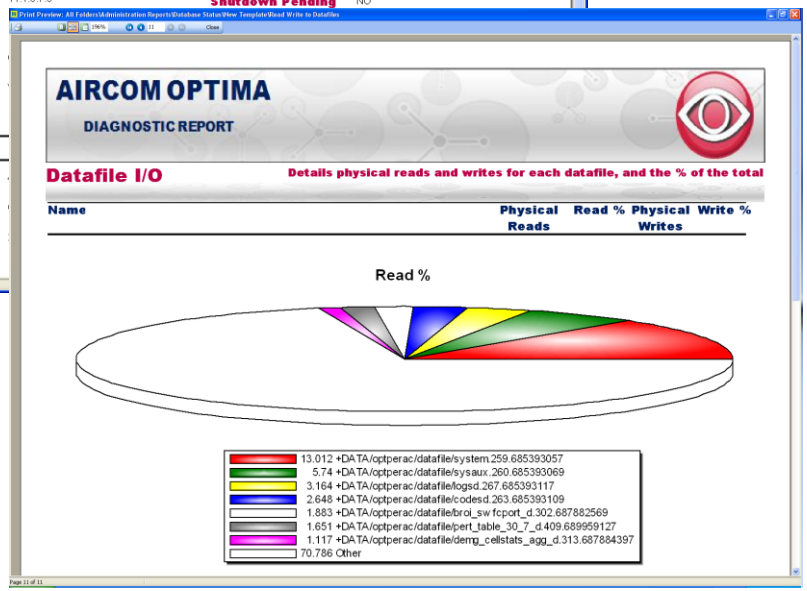
PERFORMANCE	Notes
E2E Service Performance*	Application response times for common applications i.e. HTTP, RTP, SMTP, DNS etc *Dependant upon availability of external or router based probes, Cisco IP SLA, Juniper RPM, Cisco Netflow, Juniper J Flow ** rtp only for IP CS Core, DNS verfication for Gn and Gi Network jitter, delays, packet loss, throughput, congestion, availability, flow sequence preservation, dns lookup times
E2E Traffic Class Performance	Network jitter, delays, packet loss, throughput, congestion, availability, flow sequence preservation
Drilldown	
Performance per Router	Availability, Measured Mean Bit rate, Mean Packet Rate, Mean Forwarding Rate, Mean Packet size, Packet loss rate
Performance per port/vlan/tunnel*	Per port/vlan/tunnel per class metrics, obtained through SNMP. Availability, Packet and byte rate, random and forced dropped packets, no buffer drops, ignores
Worst N Routers	N=30%
Reason for poor performance	Router load, Fragmentation, MPLS mapping to IP DSCP, lease capacity and utilization, link failures. L2 loops or broadcast storms.

CONFIGURATION	
Router	
Basic	Vendor, router model, OS SW Version, Root IP address(es), IP Designation = Ax,CE/ PE/ P, Is Router Dual homed, whats redundant, Max Platform Bit Rate,Max IP Packet Rate,Segmentation settings
Physical	Number of Ethernet Connections (FE),Number of Ethernet Connections (GbE),Number of Ethernet Connections (10GbE). Physical Port type (Electrical or optical)
Capacity	Processor boards (type, onboard CPU capacity, RAM), Negotiated port speeds, duplex settings
Protocols	Ip Version Ipv4, IPv6, Routing; Dynamic (OSPF,IS-IS, BGP), static/explicit routing Encryption (Ipsec) Compression enabled? MPLS utilised? VRRP (virtual router redundancy protocol) deployed on redundant links (dual homed links)
Scheduling & QoS	QoS labelling (DSCP) and mapping to Mobile layer QoS Call admission control (CAC) algorithms active for Voice, video Congestion Management Queuing algorithms active, LLQ (Low latency queuing), WFQ (weighted fair queuing), (CBWFQ) 'class based' weighted fair queuing, Priority queuing (PQ) for services such as voice, MDRR (Modified deficit round robin) queuing. Congestion avoidance algorithms;E.g RED or WRED (Weighted random early detection) to control packet loss during congestion & of course FRED ('Flow based') Bandwidth allocation algorithms; static,
Reporting	IOS features to allow Performanc reporting e.g RPM (Juniper), IOS IP SLA (Cisco)

PSCR Service Assurance
PM Functions for Success

Key PM Functionality: Mediation/ETL

- High collection, loading and parsing throughput required
  - Scaling horizontally (across hardware/VMs)
  - Scaling vertically using allocated CPU, memory and IO resources efficiently
- High availability and stability
  - Operates in an unsupervised mode – heartbeat functions for all processes
  - All programs are designed to restart and continue processing automatically
- Diagnostics/Logging
  - All components log warnings and errors to log files for rapid troubleshooting and diagnosis
  - Logs loaded into database for allowing detailed analysis and administrative reporting
- Multi-Platform Support
  - UNIX (HP, Sun)
  - LINUX (Redhat Enterprise)
  - Windows™
- Easy to configure and control (GUI)



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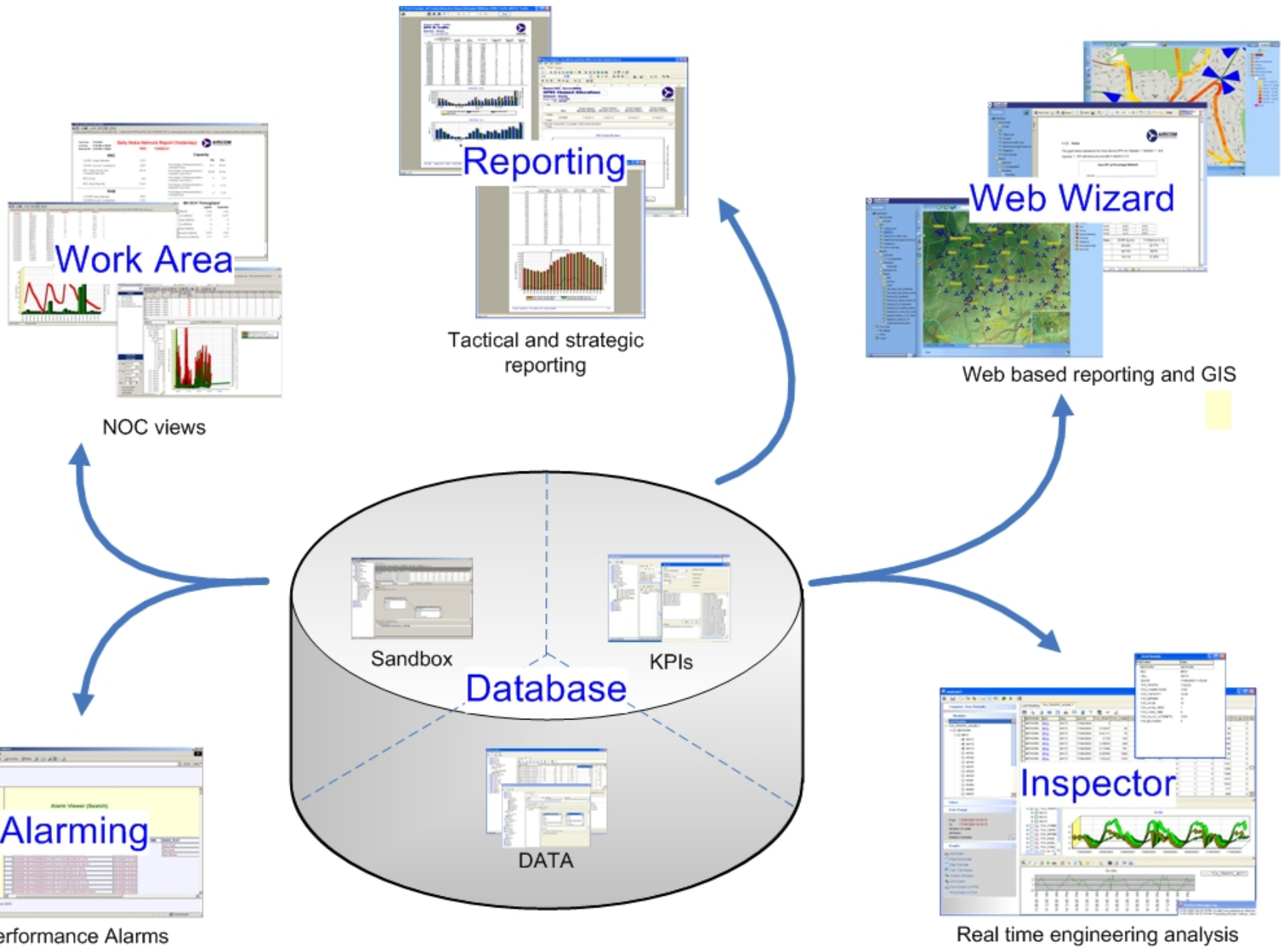
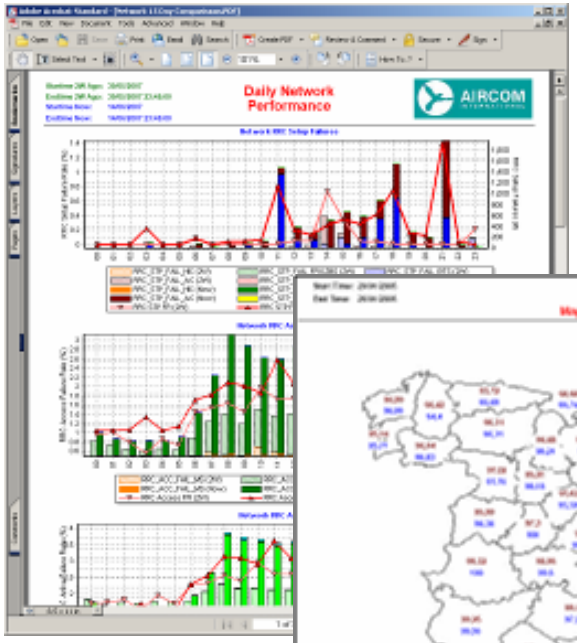
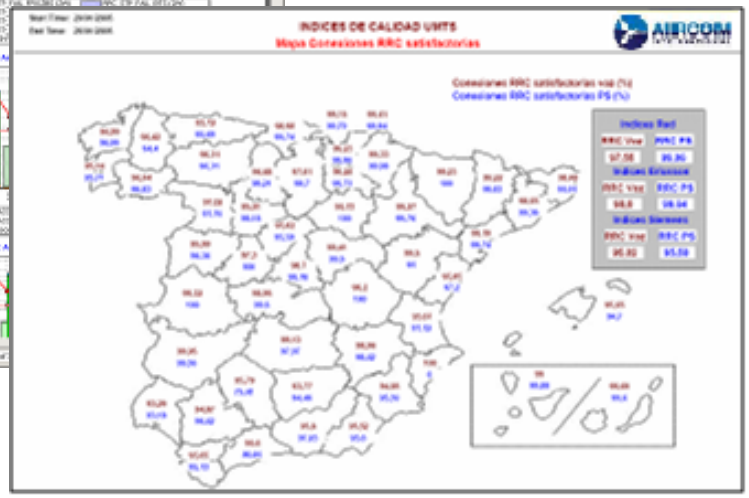
Reporting and analysis features

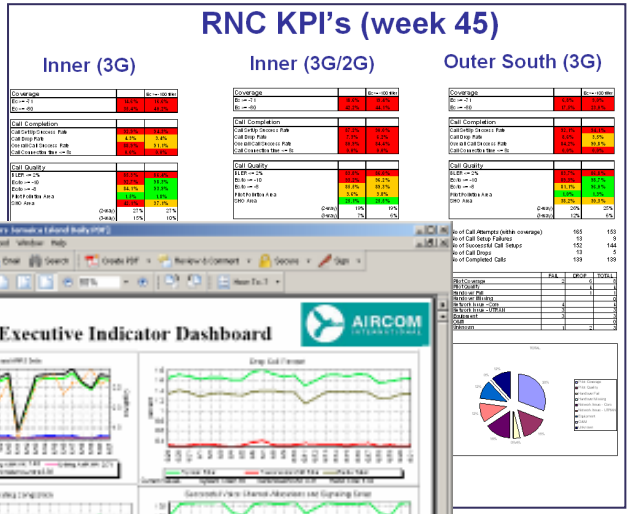


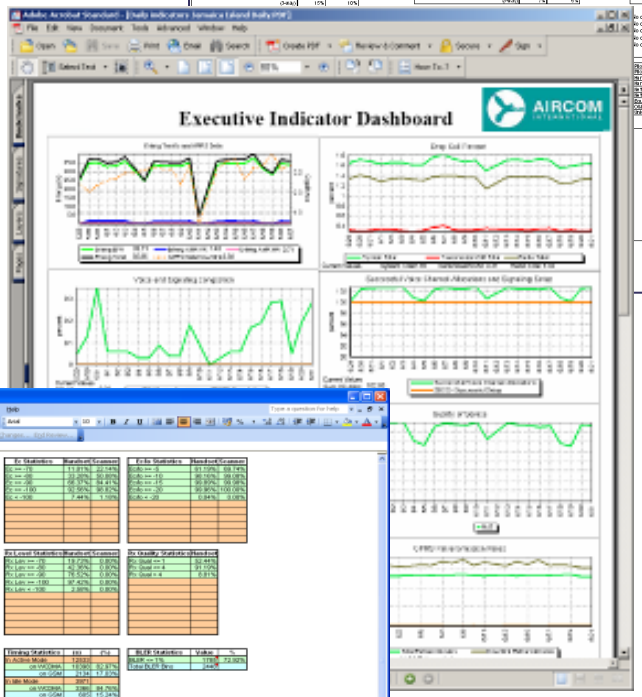
Performance Reporting: Management Reports

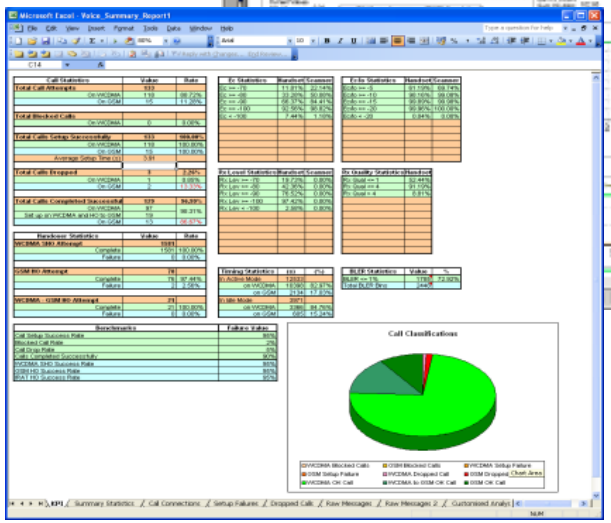
- **PM - Live Status/Daily/Weekly/Monthly Management Reports**
  - Regional/Network Summary reports
  - Customer and service level reports
  - Multi-vendor Reports
  - Multi-network Reports
  - Network Audits
  - Handset Testing











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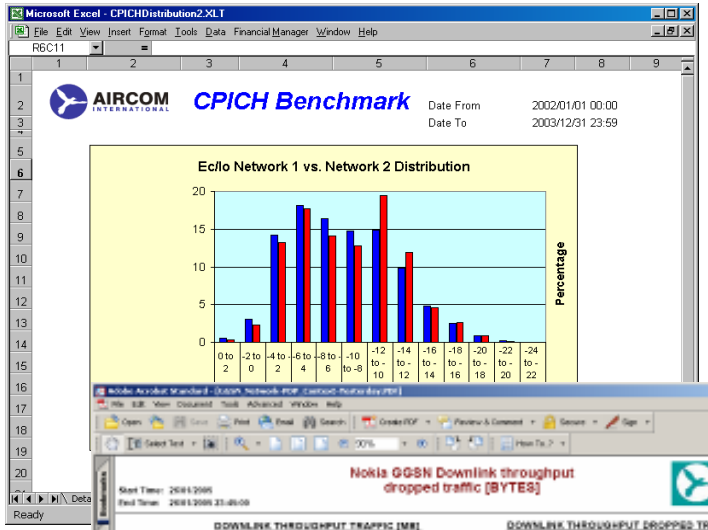
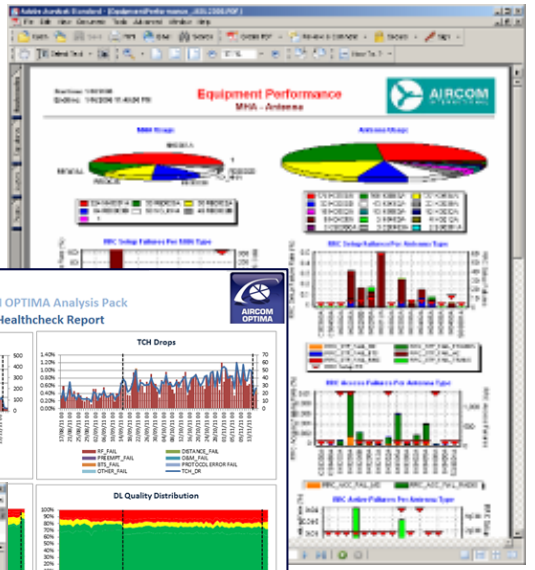
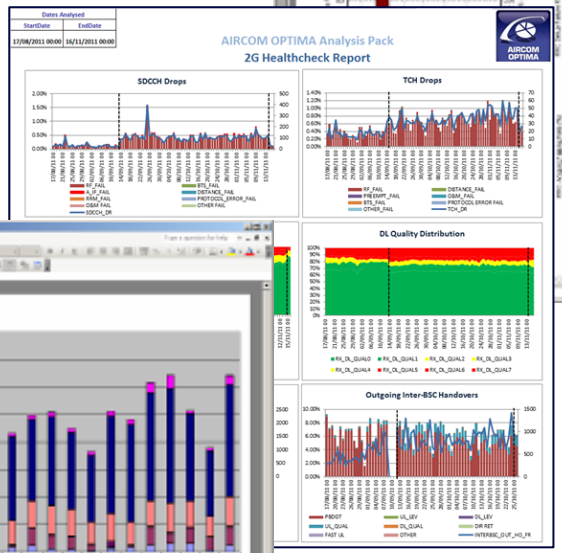
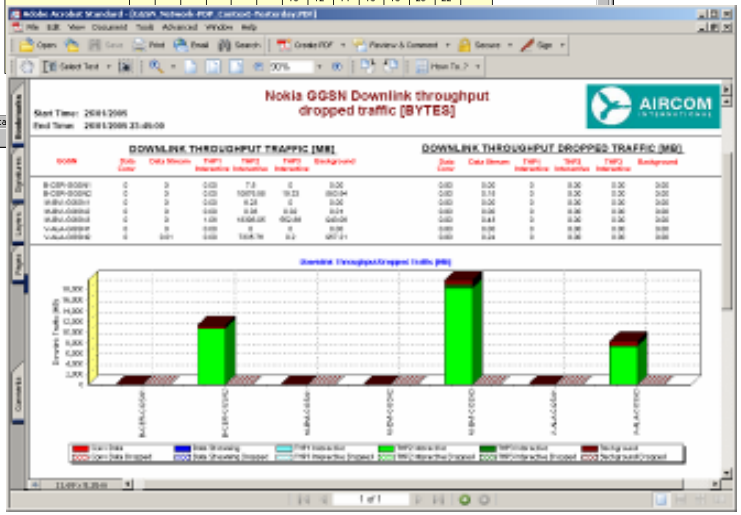
Performance Reporting: Benchmarking/Trending

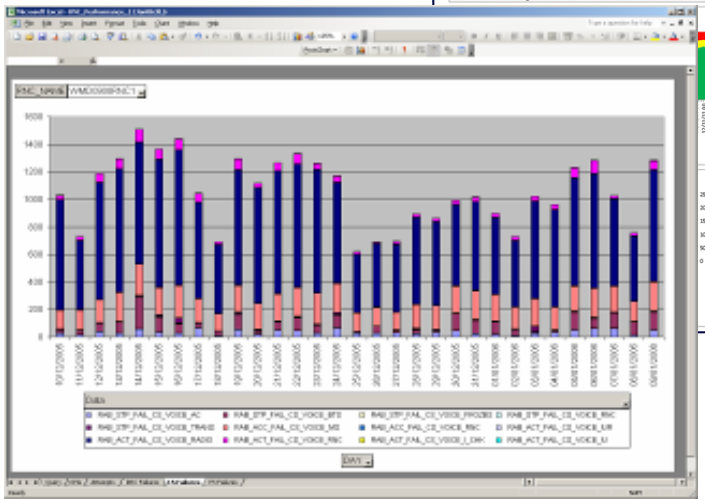
- **PM Live Status/DT Daily/Monthly/Yearly Benchmarking Reports**
  - Element, Regional, National benchmarking and trending
  - Vendor, Equipment and Handset benchmarking and trending
  - Technology, Operator, Service and Customer benchmarking and trending
  - SW, HW and configuration changes evaluation/audits





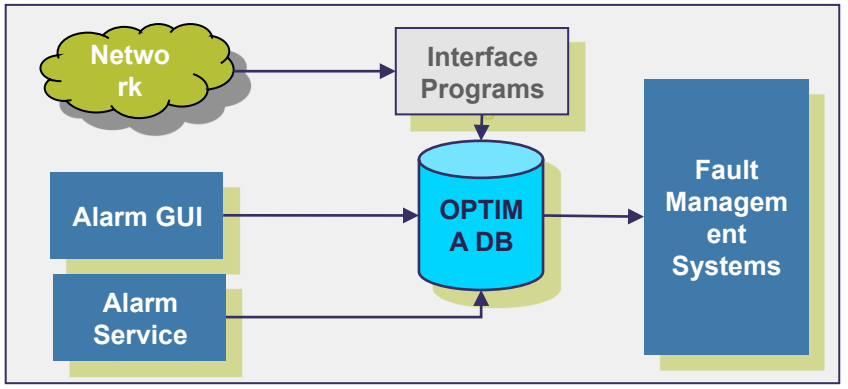


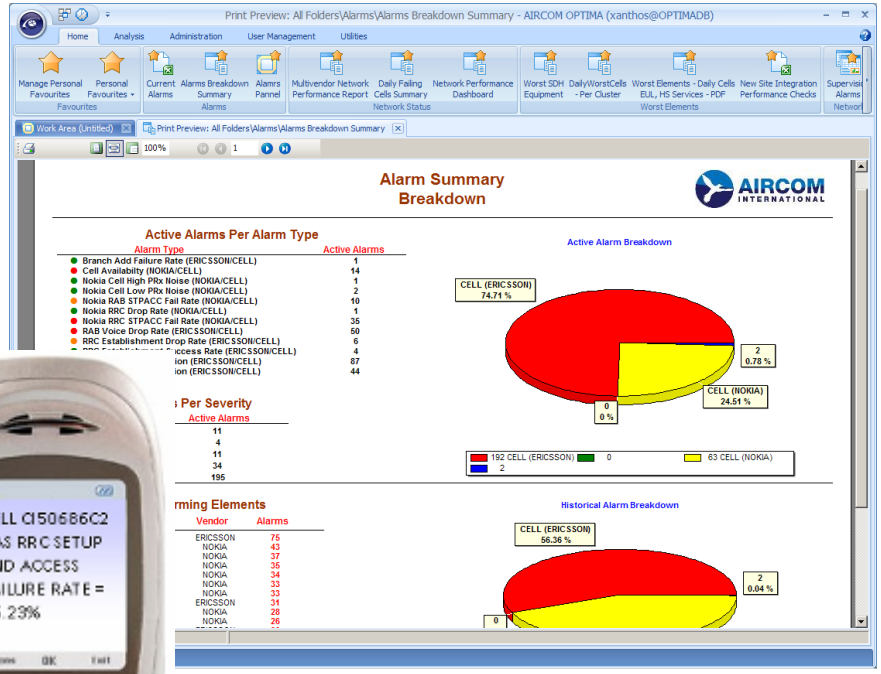




Key PM Functionality: Performance Based Alarms

- Powerful Alarm Handling
  - Automatic forwarding via e-mail and SMS
  - Automatic SNMP forwarding to other FM systems
  - Acknowledgement and commenting on alarms
- Used for Alarm definition and handling
  - Real time alarm generation during loading
  - Historical/Trend alarm generation from data in warehouse
- Total flexibility in Alarm definition
  - Use of any combination of counter/KPI
  - Multiple thresholds per alarm
  - Complex thresholds e.g. deviation from average
  - Any Trigger and Clear condition
  - Ripple Counting for repetitive triggers
  - Descriptive tagging of alarms
- Alarms stored in Database
  - Alarms stored in database for further analysis
  - Accessed by Inspector/Reports or Web
  - Knowledge/Experience through Alarm history
- Alarms Types
  - Network Performance Alarms
  - System Alarms
  - ETL Alarms





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Case Study OPTIMA real life Scalable Solution

AIRCOM's OPTIMA PM Solution has been proven to scale to 0.5 PetaBytes (500TB) and beyond

- Live OPTIMA deployment processing over 5TB per day, loading into a database 100's of TeraBytes of data online
- OPTIMA Loaders have the capability to be massively parallel and have demonstrated effective back-loading (e.g. after network outage)

Periods/day	Full day	Rows/day	Files/day	MB/day
96	1440 mins	2,886,451,200	29,790,720	4,980,960 (~5TB/day)

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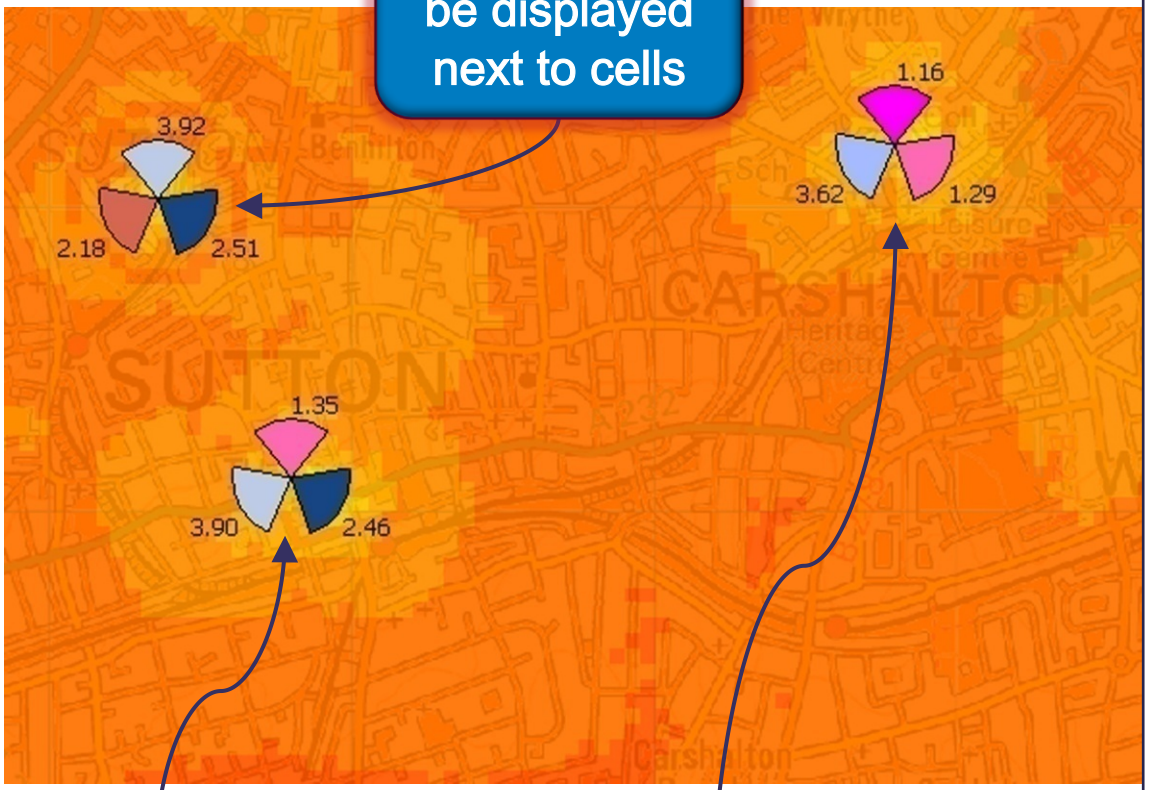
PSCR Service Assurance
Integrated Planning and PM KPIs

Integration of PM data into Planning Tools #1



PM stats can be displayed next to cells

Coverage plot from ASSET

Cells coloured by scrambling code

- **Engineers see PM stats on the 2D Map**
- **All GIS layers available**
- **Playback functionality of performance events**
- **Hierarchy populated automatically from planning software.**
- **Query across systems. Planning data with configuration data and performance statistics.**

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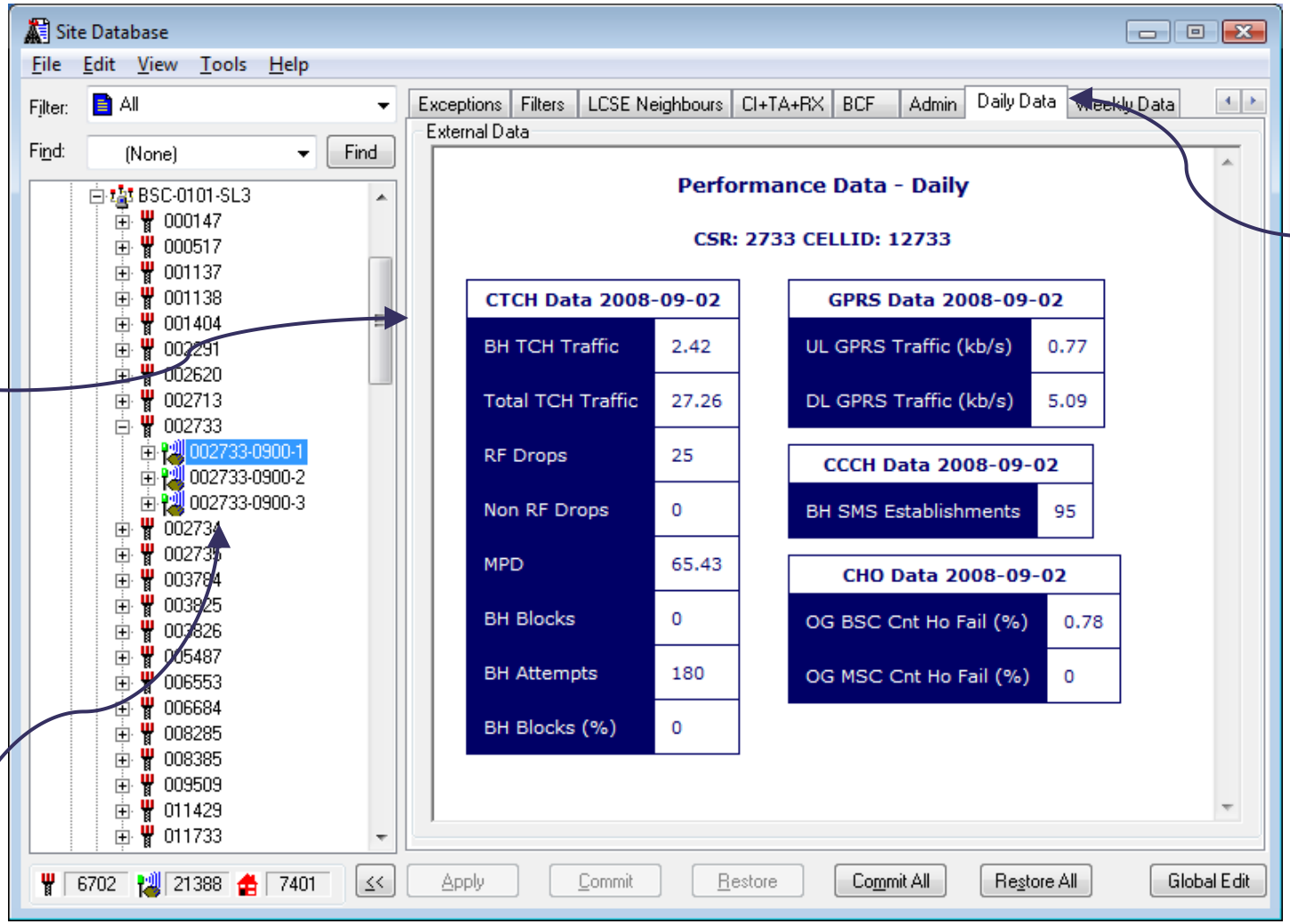
Integration of PM data into Planning Tools #2

PM stats can be displayed next to cells on site database



Different tabs for daily and weekly stats

Stats are specific to a cell or an element

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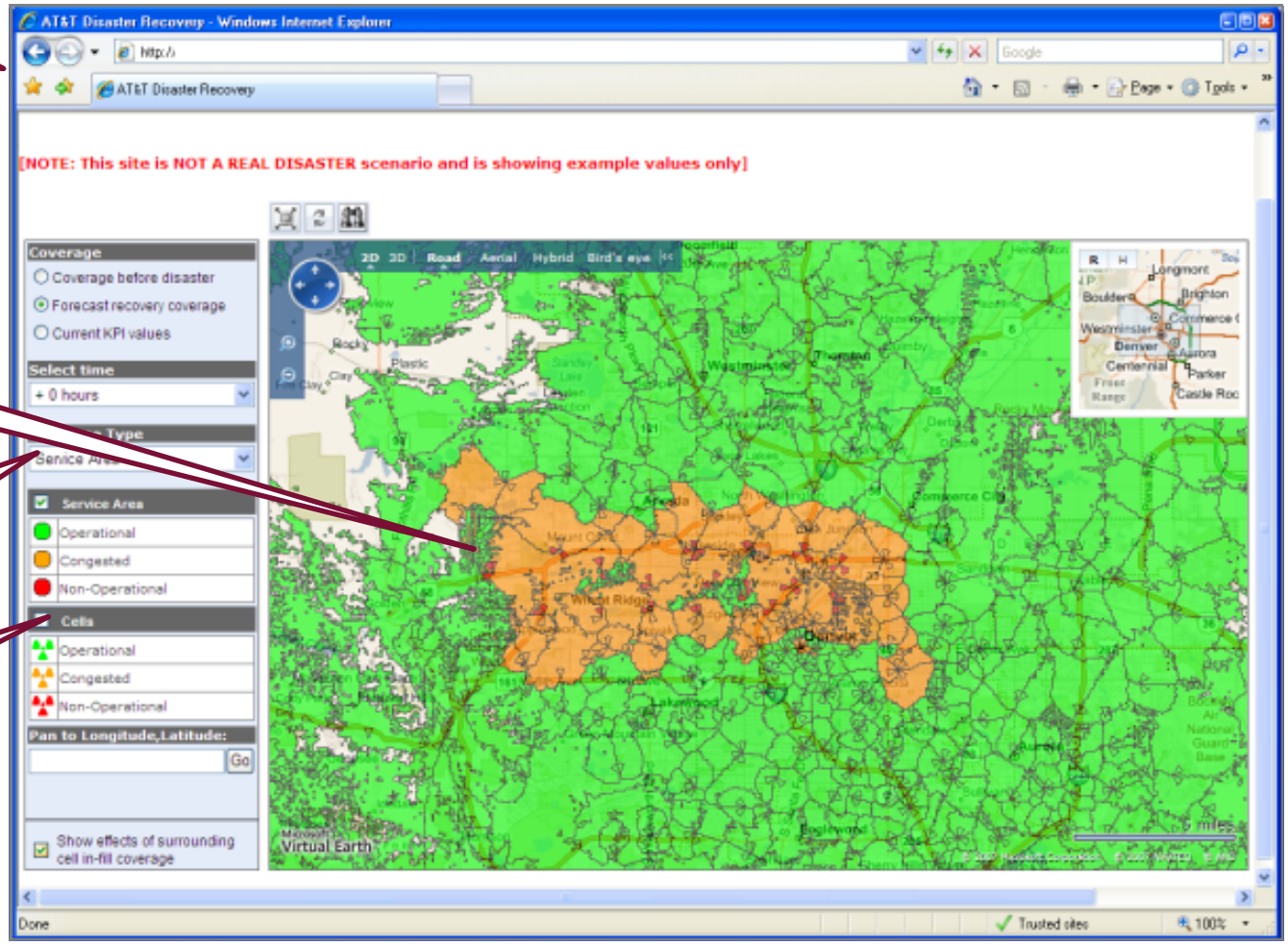
Example Disaster Reporting and Coverage Viewer

Presentation of a Disaster in a GIS

Radio re-propagation shown as part of demo

Simple Controls to set data that is displayed

Displaying Cells out of service and Performance Data



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Thank You

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