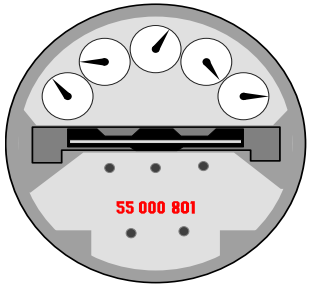
Substation Integration and Automation

UMN Internet-Based Monthly Seminar Series
April 10, 2007

John McDonald, P.E.
VP, Automation – Power System Automation
IEEE PES President, IEEE Fellow

Intelligent Electronic Device (IED)

- **Any device incorporating one or more processors with the capability to receive or send data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers)**

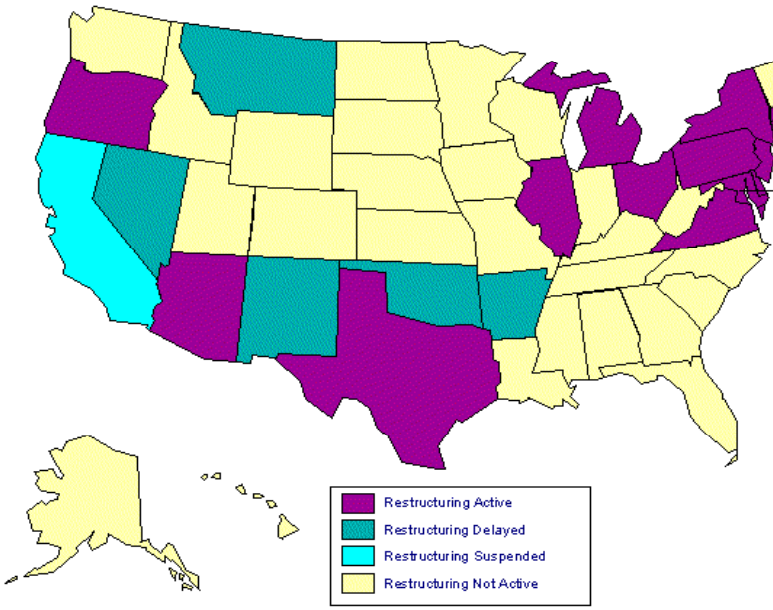


IED Interface Modules

- Eliminate Interface Modules by Putting Functionality in IED
  - Addressability
  - Protocol Conversion
  - Report-by-Exception
  - Data Filtering
  - Remote Configuration (Pass-Through)
  - Communication Physical Interface
  - Calculations and Time Stamping

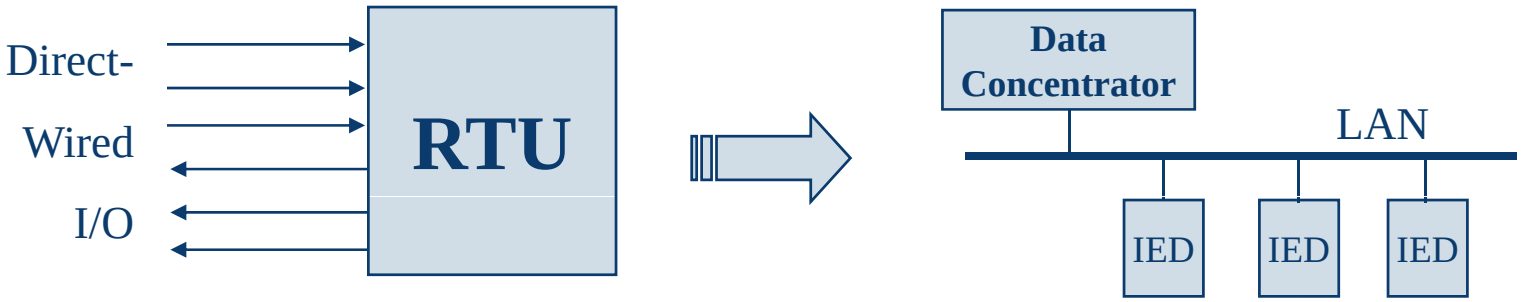
Why Needed? Why Now?

- ***DEREGULATION & COMPETITION***
  - *Deregulation driving actions of most utilities*
  - *Major driving forces:*
    - *Improved power quality and service reliability*
    - *New energy related services and business areas*
    - *Lower cost of service*
    - *Information needed for improved decision making*
  - *SA: A proactive response to these forces*



Why Needed? Why Now?

- ***DEVELOPMENT OF IEDs***
  - *Rapid development and deployment of Intelligent Electronic Devices (IEDs)*
    - *Protective relays*
    - *Meters*
    - *Equipment condition monitors*
  - *IEDs have become an integral part of Substation Automation systems*
  - *Technological developments have made SA Systems less expensive and more powerful*



Why Needed? Why Now?

- ***ENTERPRISE-WIDE INTEREST IN INFORMATION FROM IEDs***
  - *"Operational" Data*
    - *Amps, volts, watts, VARs, fault location, switchgear status*
  - *"Non-Operational" Data*
    - *Equipment condition*
    - *Fault event and power quality data (waveforms)*
  - *Persons working outside the control room want access for improved decision making*

Why Needed? Why Now?

- ***IMPLEMENTATION AND ACCEPTANCE OF STANDARDS***
  - *Confusion over industry communication standards is diminishing*
  - *International standards have become reality*

UCA2 ⟺ IEC61850

  - *Standards based implementation projects underway at <u>many</u> electric utilities*
    - *Widespread use of* **de facto** *standards for IED communications (DNP3, Modbus. Modbus+)*
    - *Some use of* **de jure** standards (UCA2/IEC61850)

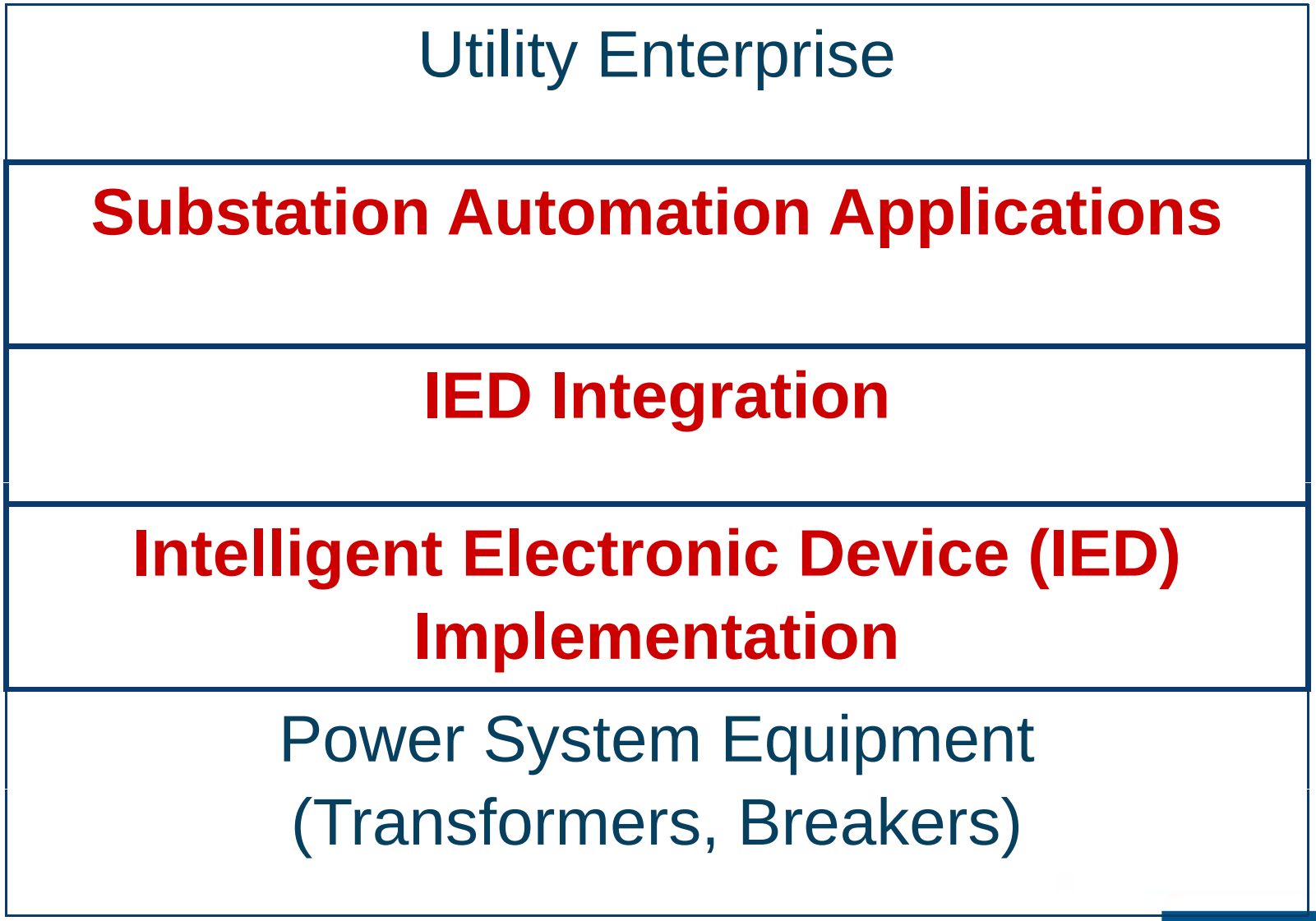
KEMA

Leading obstacle to implementing Substation Automation is:

"Economic/Business Justification Case Not Made"

(Source: Report by Newton-Evans Research Company, 1997)

Substation Integration and Automation Levels



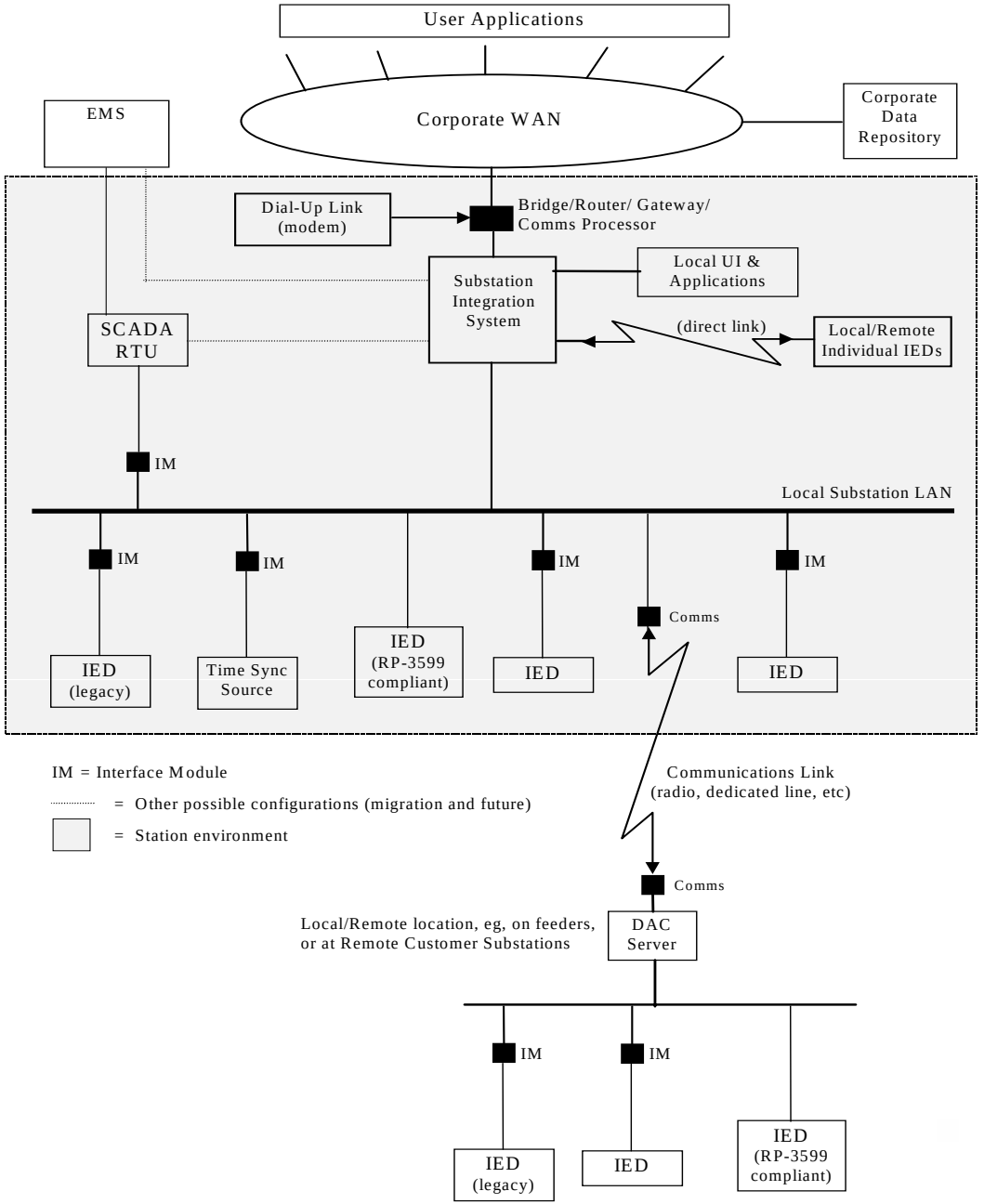
Communication Paths From Substation

- Two second data to SCADA system (operational data – extracted using industry standard protocol such as DNP3)
- On demand data to utility information server or data warehouse (non-operational data – extracted using IED vendor's proprietary ASCII commands)
- Remote access from remote site to isolate a particular IED (also called "pass through" or "loop through")

Communication Paths From Substation (continued)

<table>
<tr><td colspan="3">Utility Enterprise Connection</td></tr>
<tr><td>SCADA Data to MCC</td><td>Historical Data to Data Warehouse</td><td>Remote Dial-In to IED</td></tr>
<tr><td colspan="3">Substation Automation Applications</td></tr>
<tr><td colspan="3">IED Integration Via Data Concentrator/Substation Host Processor</td></tr>
<tr><td colspan="3">IED Implementation</td></tr>
<tr><td colspan="3">Power System Equipment (Transformers, Breakers)</td></tr>
</table>

Example of "Primary" Substation and "Secondary" Substation



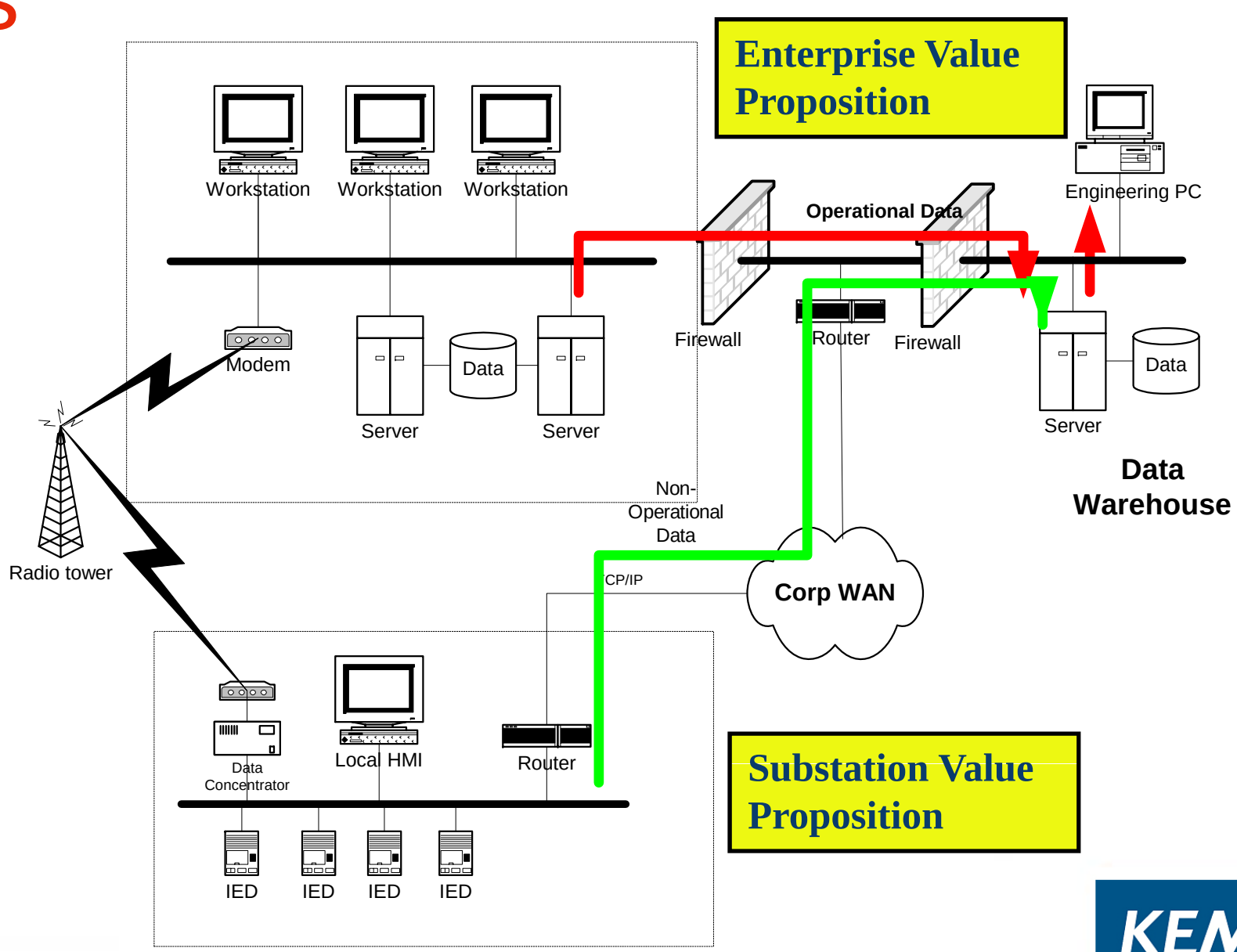
Primary Substation

Secondary Substation

Primary Substation Automation System

Secondary Substation Automation System

Operational and Non-Operational Data Paths



Local vs. Enterprise Data Marts

- Local historian at substation level is a component of the Substation Automation System (e.g., PC with local substation HMI and historical data archiving) and is designed for Data Mart integration
  - Ability to push data From substation to enterprise Data Mart based on time, demand or event triggered
  - Enterprise Data Mart can pull data from local Data Mart in substation

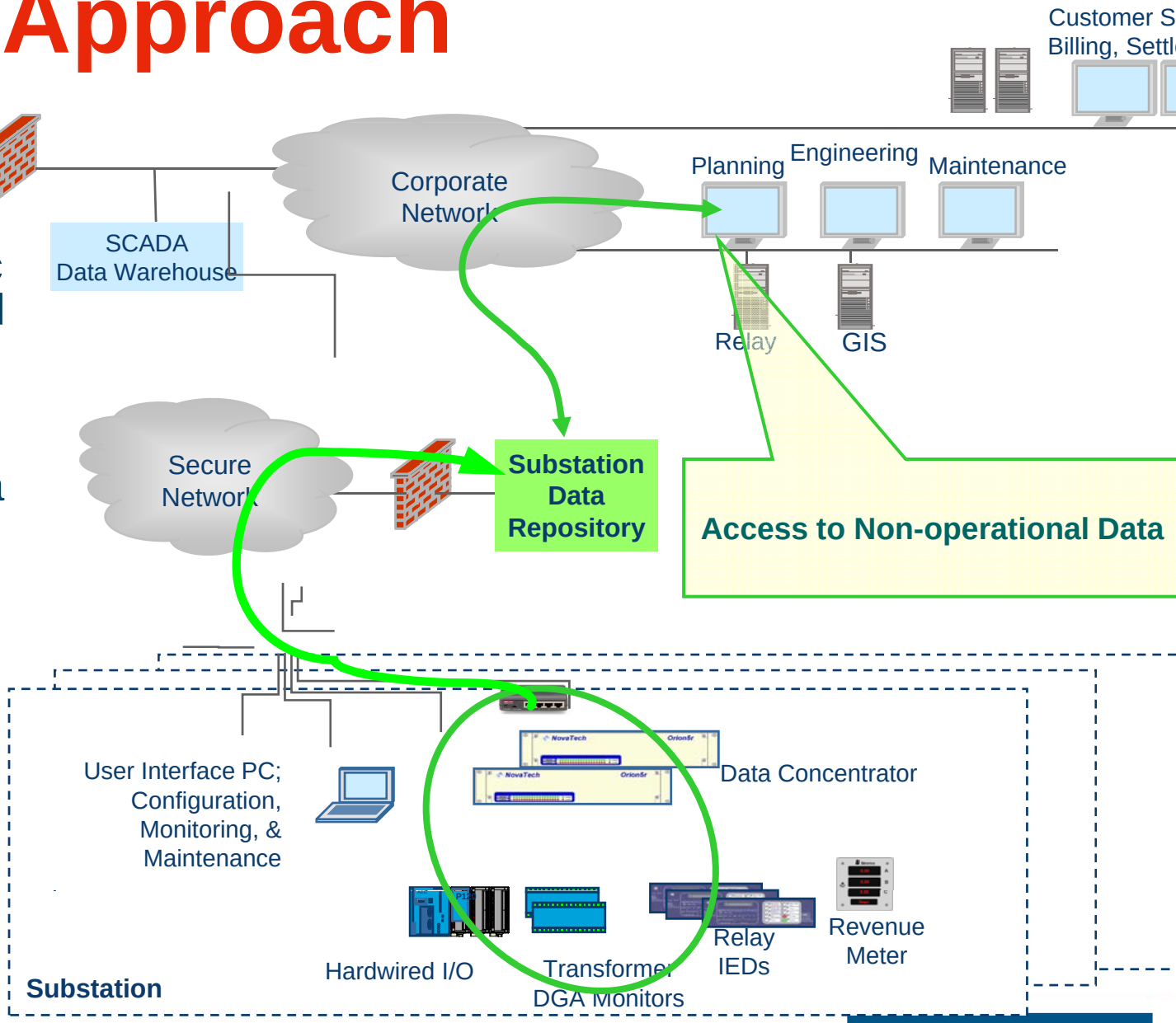
The Virtual Enterprise Data Mart

- Integrates Data from Many Sources
- Manages Consistency and Owner of Record
- Supports Applications That Need to Reference Many Different Data Types
  - Alarm Files
  - Historical Loadings, Voltages, etc
  - Maintenance Records
  - Design Information
  - Fault Targets and IED ASCII Files
  - Waveform Data
  - GIS and Asset Data
  - Overhead Imagery and IR Imagery

KEMA

Acquisition of Non-Operational Data Files – **Basic Approach**

Use manufacture specific software (or equivalent) to **extract data from the IED** (acSELerator, TapTalk, etc **Capture the data** acquired by this software in a non-proprietary format **Transmit (push or pull) the resultant data file** to a shared drive on the corporate network **Enable authorized personnel to access the data** using standard analytical tools



Approaches for Obtaining Non-Operational Data

- **Approach 1:** Download directly from the IED
- **Approach 2:** Use “Pass through” capabilities of substation data concentrator
- **Approach 3**: Local data concentrator as non-operational data server

Approach 1 - Direct Download Approach

Travel to the substation

Plug laptop containing manufacturer specific data into PC

Download data directly from the IED onto the laptop

Transfer the data to the corporate network via docking station or other data off load mechanism

Pro's And Con's

+ Low tech- low cost approach

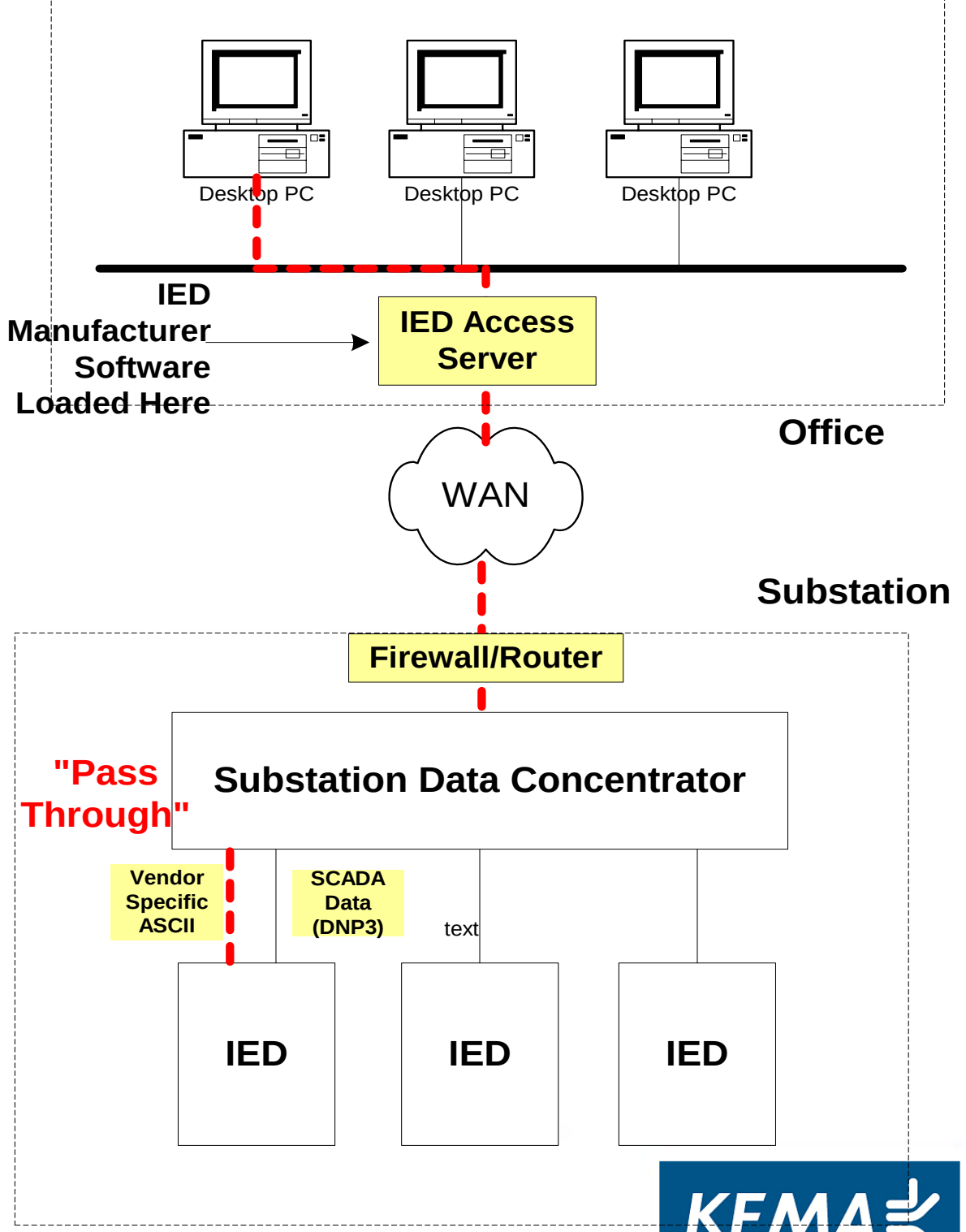
- Not continuous monitoring – delays in retrieving data

Approach 2 - “Pass Through”

Copy of IED manufacturer specific software stored on IED access server
End user connects to access server using multi-level authentication
Access server establishes a “pass through” connection to IED in question via the substation data concentrator
End user interacts with the IED and downloads the required data as though desktop PC was directly connected to the PC in the substation
Downloaded data is then copied to a shared drive as necessary
Pro’s/Con’s:

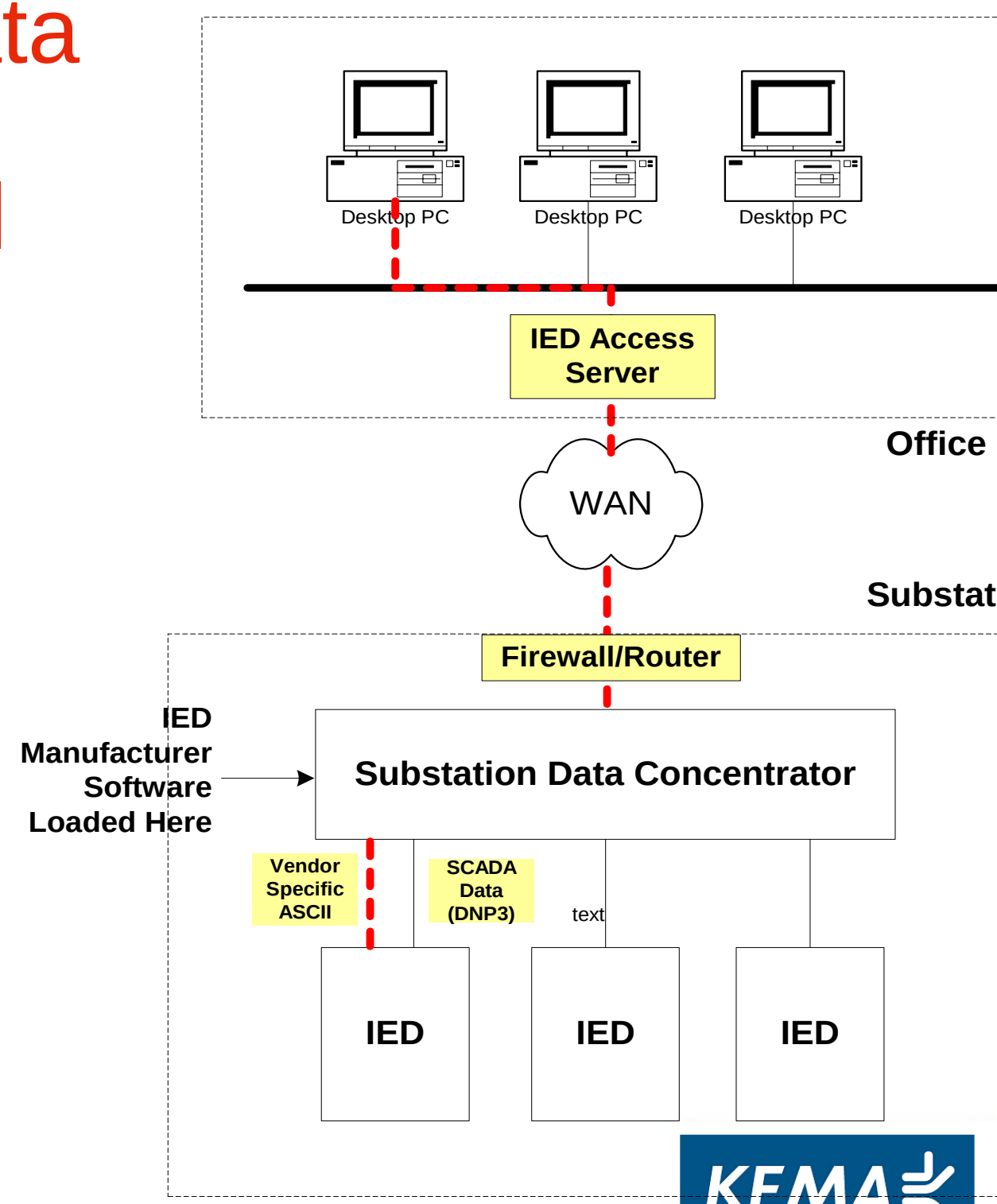
+ Technically simpler than network approach
– Promotes data silos
– Requires special IED software on each desktop PC

Today, most systems use this approach!



Approach 3 - Data Concentrator as Non-Operational Data Gateway

- IED manufacturer software (acSELerator, Tap talk, etc) or equivalent loaded onto substation data concentrator
- Data concentrator communicates directly with the IEDs to acquire non-operational data files
- Data concentrator converts data files to standard format
- Converted data file “pushed” or “pulled” into ELSI



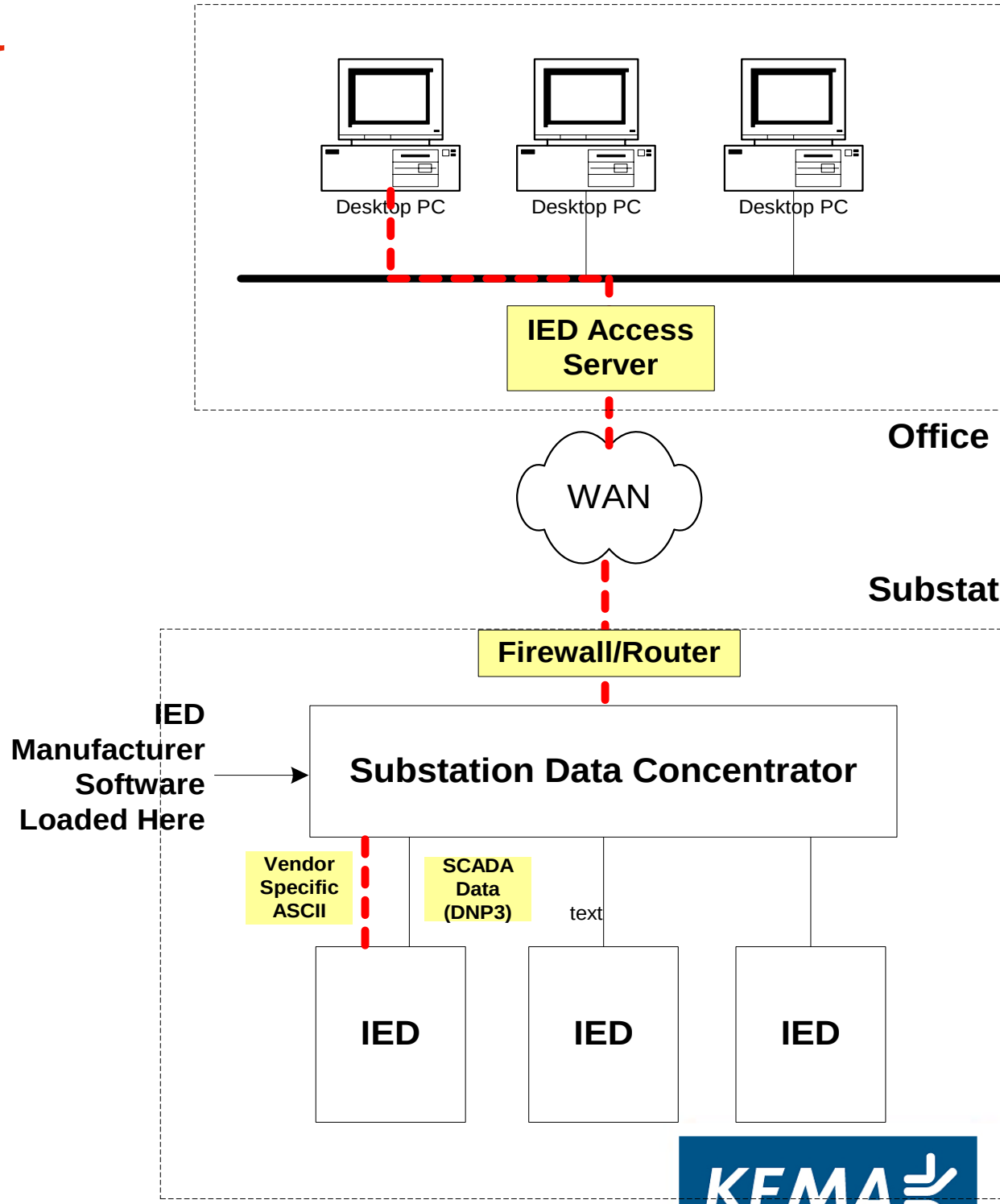
pproach 3 - Data oncentrator as on-Operational ata Gateway

Advantage of this approach:

- Fewer field devices to manage from central location – 1 SDC versus multiple IEDs
- Data files transferred over WAN using FTP, OPC or other standard method versus IED specific protocol

Disadvantage

- SDC must support the IED proprietary ASCII protocols
  - Not many do at this time



Background

- **State of the Industry…setting the table**
  - **90%+ utilities implementing IEDs**
  - **Extracting only 15% of the benefits**
  - **Few Have ELSI Architecture and IT Infrastructure in Place**
    - **Substation, Communications, Data Mart**
  - **85% remaining to be tapped – condition, performance, etc. – key indicators that drive the decisions that business users make everyday!**
  - **More and more utilities are starting to look at the problem**
  - **Enterprise data management today is where EMS was in 1975**
    - **Early Adoptors showing the way**

KEMA

Typical Current State and Implications

- **Moderate penetration of IEDs and uneven adoption of existing enterprise data management standards**
  - **No Focused Plan for IED Penetration**
- ***Continuous* condition monitoring not being done today; nor is easy retrieval of equipment historical loadings, etc.**
- **Asset Management not supported by statistical data**
- **Fault Location not Automatically Integrated with Outage Management**
- **Lack of distance to fault information**
- **Many Maintenance / Operations procedures designed around EM relays and lack of continuous condition monitoring.**
- **Makes statistical analysis and project portfolio optimization difficult**

KEMA

All the Costs, None of the Benefits

- **Current IED Deployment Rates Will NOT:**
  - **Improve reliability**
  - **Produce cost reductions**
  - **Increase operations efficiency**
  - **Allow process improvements**
- **But Current Rates Will:**
  - **Guarantee multiple technology families deployed across regions / districts**
  - **Data silos will persist**
  - **Prolong existence of EM relays**
    - **Which in turn prolongs existence of “RTU” equipment**

KEMA

Opportunity Matrix - Examples

	Functions	Improve Reliability	Reduce Electrical Losses	Reduce Capital Expenditures	Reduce O&M Costs	Increase Revenue
Substation Automation	**Implementation**					
	Corporate Data Repository		√			
	Local User Interface and/or Elimination of Convertional displays / Controls			√		
	Reduce Panel Space/Wiring - Smaller Substation Size			√		
	Integrated Protection	√		√		
	Automation					
	Equipment Condition Monitoring	√		√	√	√
	Automated Load Restoration	√			√	√
	Feeder Automation Support	√	√		√	√
	Dynamic Equipment Rating			√	√	√
	Disturbance Data Analysis	√			√	√
	Adaptive Relaying	√			√	√
Asset Management						
	Condition-Based Inspection & Maintenance	√		√	√	√
	Improve Contingecy Plans - Minimize Risk	√		√	√	√
	Life Extension Plans			√		
	Condition-Based Replacement	√		√	√	
	"Portfolio" Management & Optimization			√	√	√
	Coordinated Asset Registry, Maintenace, Engineering & Operations	√		√	√	

KEMA

Best Practice Examples

- **Comparable utilities are exploiting IEDs to achieve improved performance (reliability) at lower costs (Capital and O&M)**
  - **Fault location and dispatching**
  - **Condition Based Maintenance**
  - **Asset Management**
  - **Productivity improvements**

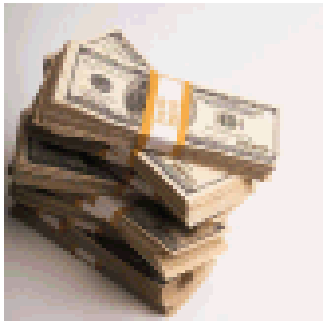
- **These utilities have a broad strategy for deploying and integrating IEDs and IT Systems to achieve business objectives**

KEMA

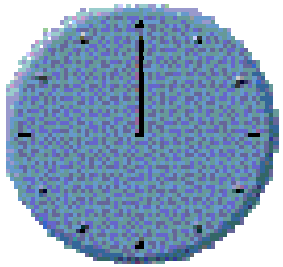
Project Benefits – Case Study

Financial

- Reduce reactive power flow
- Improve O&M efficiencies
- Reengineer work processes



Reliability



- Maintain power system control integrity
- Reduce Customer Average Interruption Duration Index (CAIDI) by 10 minutes on monitored circuits
- Improve maintenance to key power system components

Environmental

- Reduced reactive power = Reduced emissions
- Reduced emissions = Improved air quality

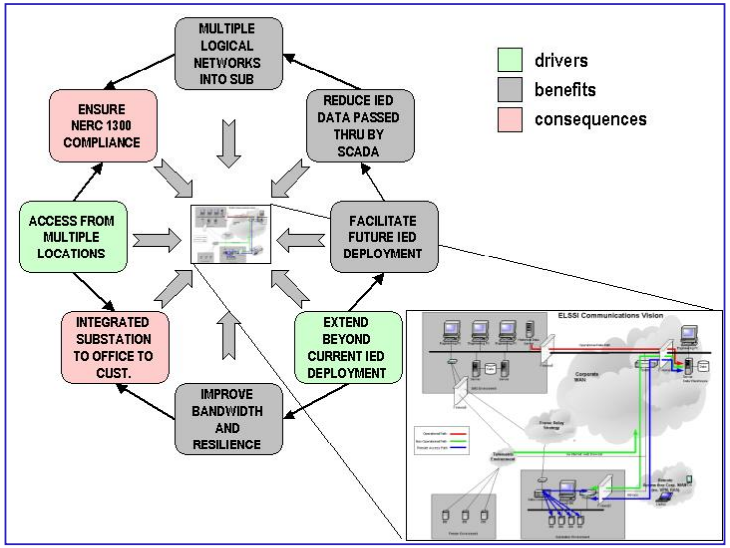
Reported Benefits - Examples

Description	First Cost $K	Annual Cost $000	Annual Benefit $000	Annual Benefit
IEDs Integrated with OMS –	$1665	$285	$1800	7 minutes SAIDI
“	*$3760*	*$610*	*$2320*	*3-5 minutes SAIDI*
IED Driven CBI	*$9500*	*$685*	*$1300*	
“	**$2780**	**$380**	**$1150**	**5 yrs reported data**
CBI Driven CBM	*$3800*	*$1200*	*$2750*	*Incremental to CBI*
Dynamic Equipment Ratings	$1400	$450	$850	Large US Pool Tie
“	$2900	$700	$1500	10 major lines
Intelligent Substation Alarming	$2780	$380	$1150	Targeted; smaller utility
Congestion Cost Reduction				No data yet but believed significant in some cases

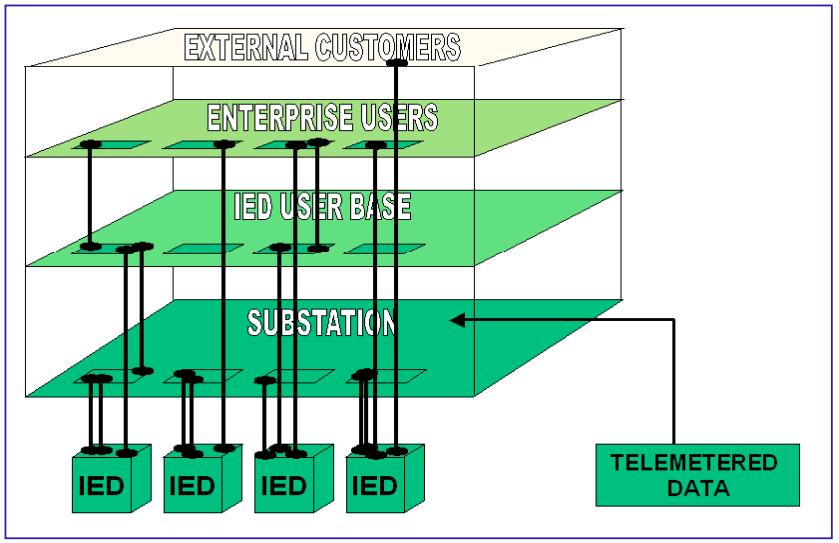
Italics = projected

Enterprise Data Management Vision

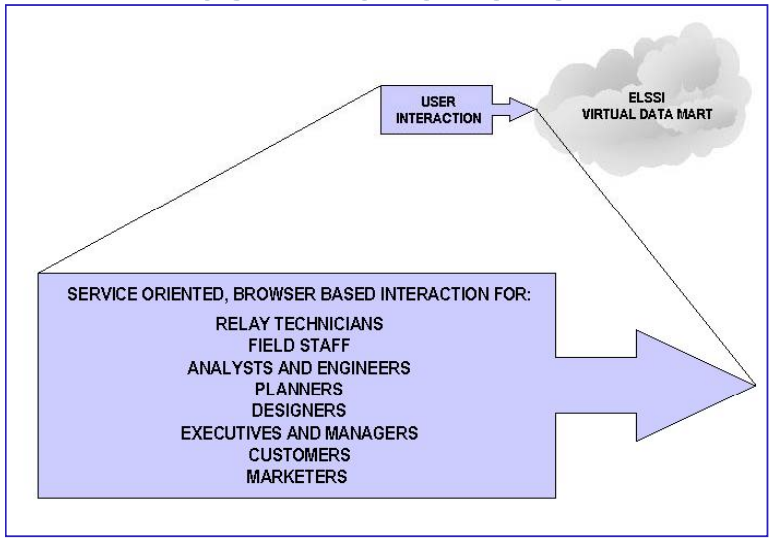
COMMUNICATIONS



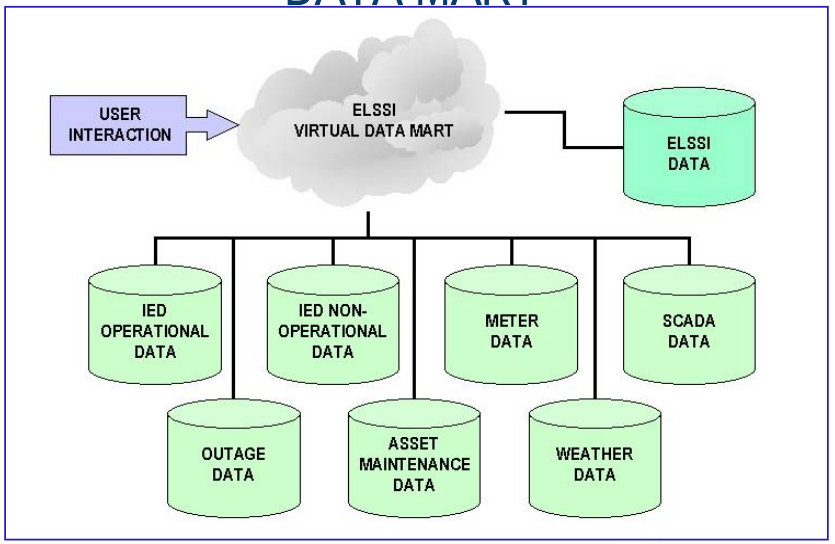
USER LEVELS



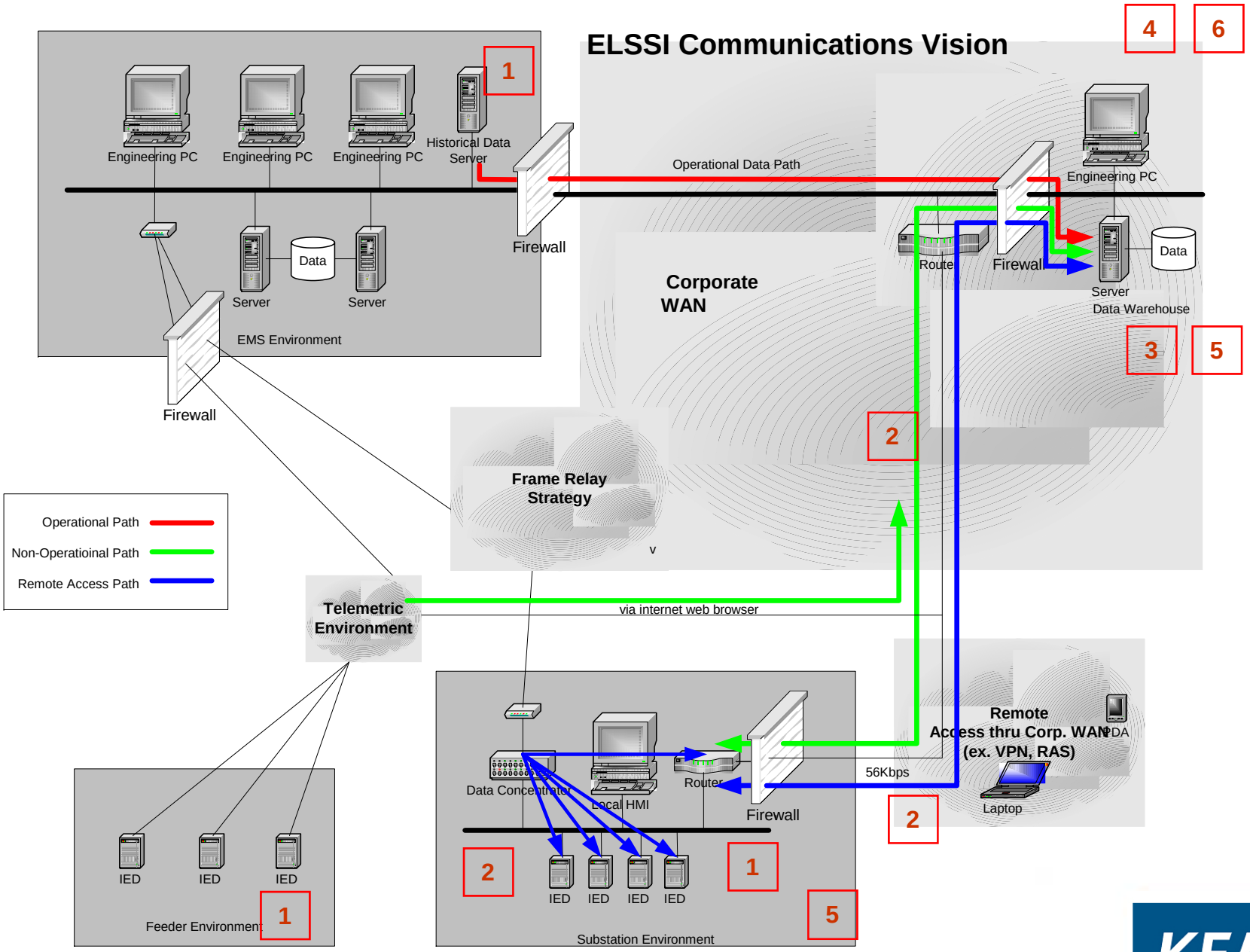
USER FUNCTIONS



DATA MART



Enterprise Data Management Overview



Overview…continued

- Substation [1]
  - IED Data Templates
  - Substation Integration Architecture
  - Substation Data Management (Operational and Non-Operational Data)
  - Substation Classes
  - Benefit Cost Analysis (BCA) for Substation Integration and Automation Candidate Functions
  - Start with Substation Data Requirements, then Reach Out to Feeders, Power Plants, etc.
- Communications Infrastructure [2]
  - Within Substation
  - Substation to Enterprise
  - Within Enterprise

KEMA

Overview…continued

- Enterprise Data Management/Data Mart [3]
  - Data Requirements Matrix
  - Virtual Data Mart
- Business Processes [4]
  - Condition Based Inspection (CBI)
  - Condition Based Maintenance (CBM)
  - And Other Processes
  - Business Case Analysis for Business Processes
- Implementation [5]
  - Substation
  - Virtual Data Mart
- Applications [6]

IED Data Extraction - Standardization

- **Determining which data to extract from each IED**
  - Data Requirements Matrix (generated from interviews)
    - Requirements by user group (protective relay, predictive maintenance, planning, etc)
    - Consolidated requirements by circuit element (transformer, line, etc)
  - IED templates
    - Use results of Rata Requirements analysis to determine what data should be extracted from each IED

Sample Data Requirements Matrix (By User Group)

User Group	Circuit Component	Data Item	Type	Units	Source
Protective Relay Engineering	Transmission lines, transformers, and busses	Fault oscillograph records; 3 ph voltages and currents,	Datafile		Wavew in
Protective Relay Engineering	Transmission lines, transformers, and busses	Sequence of events reports: breaker contacts, relay targets, etc.	Datafile		Wavew in
Protective Relay Engineering	Transmission, subtransmission, or distribution circuit	Line current A,B,C phase	AI	Amperes	EMS
Protective Relay Engineering	Transmission, subtransmission, or distribution circuit	Line-to-neutral voltages AN, BN, CN	AI	Kilovolts	EMS
Protective Relay Engineering	Circuit Breaker	Open/closed status	DI		EMS
Protective Relay Engineering	Protective Relays	Active settings group	AI	N/A	Protective relay IED via dialup
Predictive Maintenance	Load Tap Changer	Voltage (source and load side)	AI	Kilovolts	EMS
Predictive Maintenance	Voltage Regulator	Raise/low er tap draghands	AI	Taps	Obtained manually
Predictive Maintenance	Substation Transformer	Dissolved gases: H2 content	AI	Percent	MMS
Predictive Maintenance	Substation Transformer	Dissolved gases: Carbon monoxide content	AI	Percent	MMS
Predictive Maintenance	Substation Transformer	Dissolved gases: Acetylene content	AI	Percent	MMS

KEMA

Sample Data Requirements Matrix (By Circuit Component)

Circuit Component	Data Item	Format	Units	Source
Circuit Breaker	Average close electrical operating time	AI	milliseconds	SL 2032
Circuit Breaker	Average close mechanical operating time	AI	milliseconds	SL 2032
Circuit Breaker	Average trip electrical operating time	AI	milliseconds	SL 2032
Circuit Breaker	Average trip mechanical operating time	AI	milliseconds	SL 2032
Circuit Breaker	Breaker w ear percentage trip contact A,B,C	AI	%	SL 2032
Circuit Breaker	Close contact A,B,C total current	AI	dc amps	SL 2032
Circuit Breaker	Close contact A,B,C total energy	AI	megajoules	SL 2032
Circuit Breaker	Last electrical close operating time A,B,C	AI	milliseconds	SL 2032

Sample IED Template

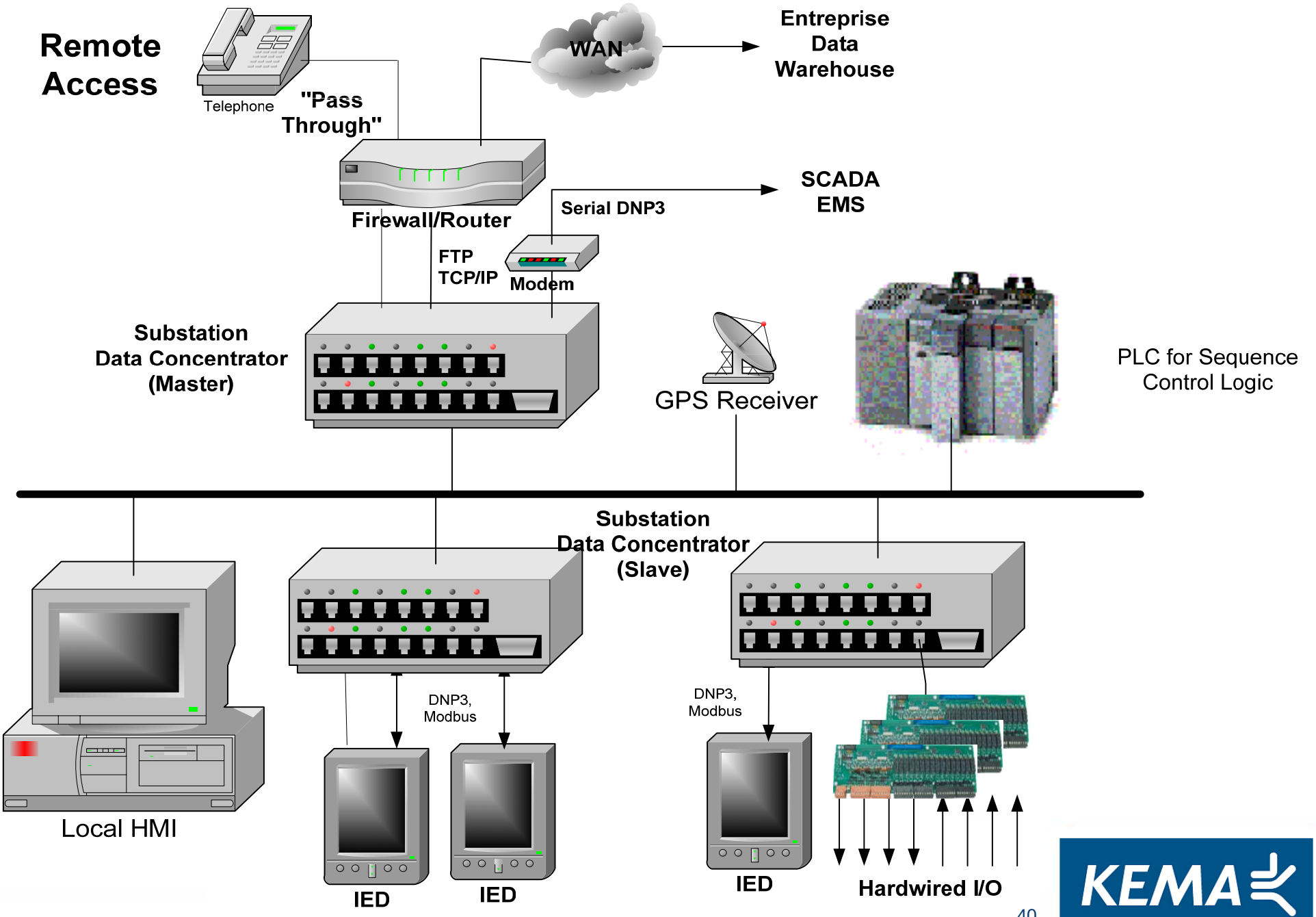
SEL-352 Relay Data Template			
DNP Object Type	**Index**	**Description**	**Circuit Breaker**
20,22	00	Active settings group.	
20,22	01	Breaker Trip A.	X
20,22	02	Breaker Trip B.	X
20,22	03	Breaker Trip C.	X
20,22	04	Breaker Close A.	X
20,22	05	Breaker Close B.	X
20,22	06	Breaker Close C.	X
20,22	07	Failed CB Trip Resistors Put in Service.	
20,22	08	Failed CB Close Resistors Put in Service.	
20,22	09	52A contradicts voltage.	
30,32	23	Avg. Electrical Time (ms) TRIP A	X
30,32	24	Avg. Electrical Time (ms) TRIP B	X
30,32	25	Avg. Electrical Time (ms) TRIP C	X
30,32	26	Avg. Electrical Time (ms) CLOSE A.	X
30,32	27	Avg. Electrical Time (ms) CLOSE B	X
30,32	28	Avg. Electrical Time (ms) CLOSE C	X
30,32	29	Avg. Mechanical Time (ms) TRIP A	X
30,32	30	Avg. Mechanical Time (ms) TRIP B	X
30,32	31	Avg. Mechanical Time (ms) TRIP C	X
30,32	32	Avg. Mechanical Time (ms) CLOSE A	X
30,32	33	Avg. Mechanical Time (ms) CLOSE B	X
30,32	34	Avg. Mechanical Time (ms) CLOSE C	X
30,32	35	Last Electrical Time (ms.) TRIP A	X
30,32	36	Last Electrical Time (ms.) TRIP B	X

KEMA

Develop Design Characteristics for Standard Sub Auto Configuration

- Handling of three data paths:
  - Operational data
  - Non-operational data
  - Remote access (administrative data)
- IED interfaces and protocols (op, non-op, and admin data)
- Local user interface
- Cyber security
- Local data processing capabilities (per-processing and sequence control logic)
- Handling of hardwired data items
- Time synchronization

Representative SA Architecture



Thank You!