India SMART UTILITY Week 2020

March 03 - 07, 2020 | The Lalit Hotel, New Delhi, India

ISGF India Smart Grid Forum

India Smart Utility Week 2020

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TRACK-1: TECHNOLOGIES ENABLING ENERGY TRANSITION: DIGITALIZATION

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Abstract

- Metering role in Transformation of the global energy sector
  - Fossil to zero-carbon by information and communication technology
  - More consumer participation
  - Decentralized resources
  - Human machine collaboration at user end
  - Energy efficiency and conservation
- Smart meters - two-way communication producers and consumers
- Basis for “smart grids” - detect and instantly react to local changes in generation and demand

Abstract (continued)

- Artificial intelligence (AI) / Distributed Intelligence (DI) support distributed resources on the grid
- Payment for surplus supply
- More data requires use of AI
  - Pinpointing patterns of behavior and making
  - Accurate predictions of energy demand and much more.
  - This provides an uninterrupted supply of energy solutions, all of which work together to enable the transition to net zero emissions in India.
- Additional opportunities to better manage the grid itself.

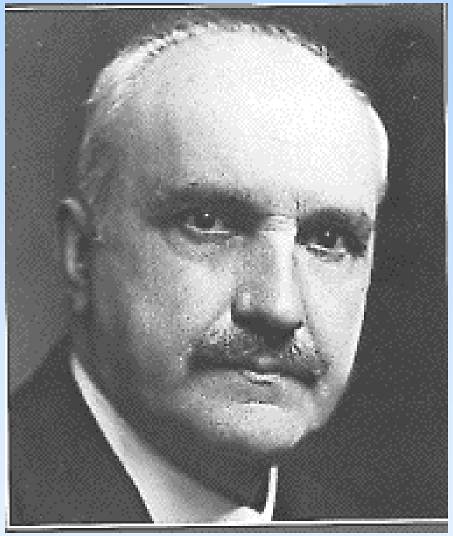
Credits for AMS material from Oncor Electric Delivery – Dallas, Texas:

- Jonathan Pettit, PE — Oncor System Metering
- Randall Schmidt — Oncor AMS Operations

Oncor's Advanced Metering System

First, a look at the Past…

George Santayana (1863-1952):

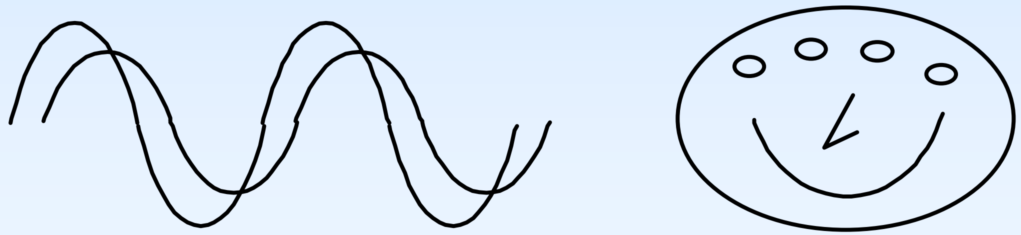


"Those who cannot remember the past are condemned to repeat it."

Life of Reason, Reason in Common Sense, **Scribner's, 1905, page 284**

In the Beginning

In the beginning there was light. And electric light was good. But electricity needed to be measured. So the electric energy meter was created. This is the story of the electricity meter.



Discovery of Electricity

- **Since classical antiquity, it has been known that some materials such as amber attract lightweight particles after rubbing.**
- Charles-Augustin de Coulomb (1736 –1806)
  - French physicist developed Coulomb's law, the definition of the electrostatic force of attraction and repulsion.
- Alessandro Volta (1745 – 1827)
  - Italian physicist known for the invention of the battery in the 1800s.
  - Voltaic Pile - 1800
- Michael Faraday (1791 –1867)
  - English scientist who contributed to the fields of electromagnetism and electrochemistry. His main discoveries include those of electromagnetic induction, diamagnetism and electrolysis.
  - Observed the relationship between current and magnetic fields.
    - **Conductor moving in a magnetic field results in electric current.**
    - **Faraday’s work inspired Tesla**
- James Clerk Maxwell (1831 – 1879)
  - Scottish mathematical physicist.
  - Formulated equations that describe electricity, magnetism, and optics as manifestations of the same phenomenon, namely the electromagnetic field.[

Electric Arc Lamp invented 1802

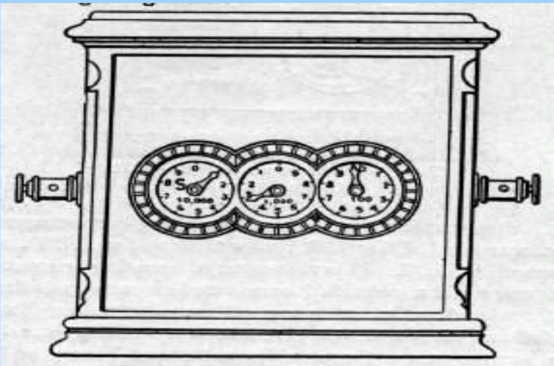
- Not practical because of lack of constant electricity supply
- Practical dynamos demonstrated by Staite and Brush in 1870's
- Brush established Brush Electric Company in 1880 to provide arc lighting

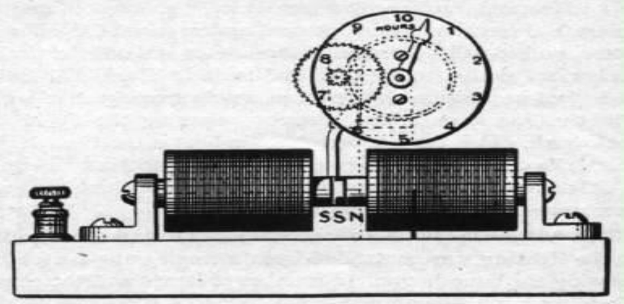
June 28, 1856: Никола Тесла (Nicola Tesla)

- Studied electrical engineering at the Austrian Polytechnic in Graz (1875)
- While there he studied uses of alternating current.
- Tesla’s dream: to work for the Edison Company

Early Electric Systems

- All lamps were similar.
  - Cost = # lamps * time
- 1872: Samuel Gardiner takes out the first known patent on an electric meter.
  - This was a DC lamp-hour meter that was a clock with an electromagnet that started and stopped the mechanism.
  - **1878:**J.B. Fuller takes out a patent on an AC lamp-hour meter that was a clock operated by an armature that vibrated between two coils.

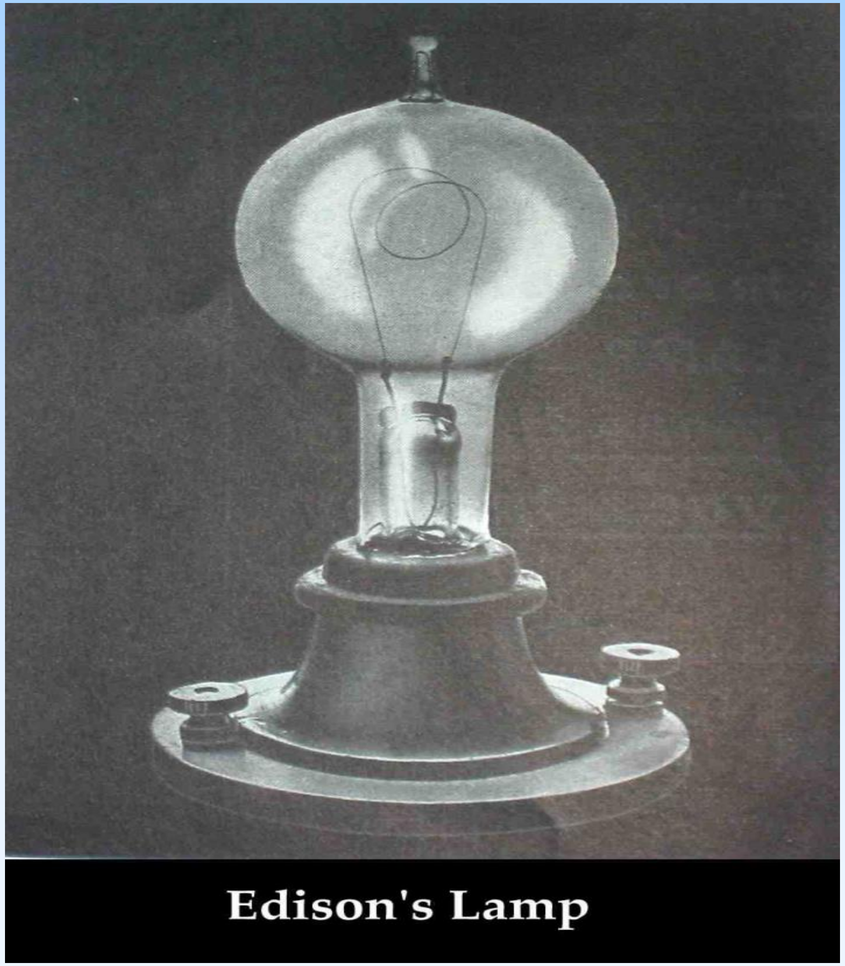




Incandescent Light Bulb

- October 21, 1879 – Thomas Alva Edison invents electric light bulb
- Electricity originally used to provide light only
- Edison system: Batteries delivered DC directly to user facilities
- Batteries delivered by delivery wagon – the “Culligan” model

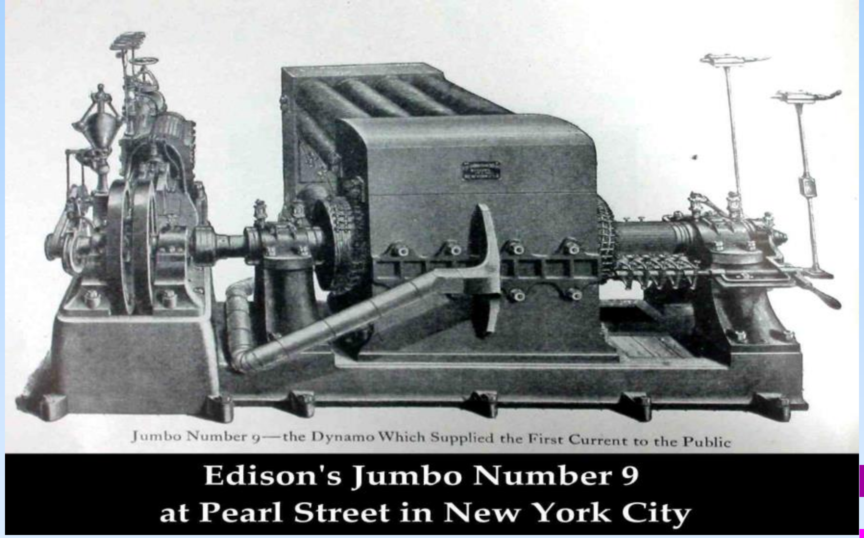
1880: Edison Illuminating Company formed

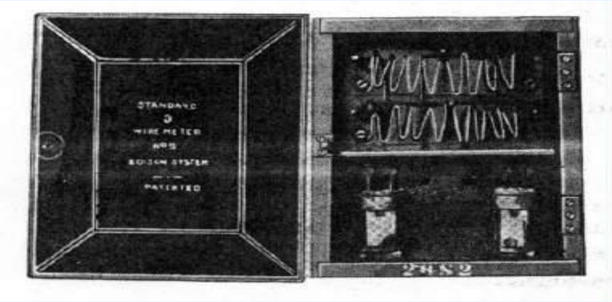


- September 4, 1882: First central power plant-Pearl Street Station in lower Manhattan
- One generator produced power for 800 electric light bulbs.
- In 14 months, Pearl Street Station had 508 subscribers and 12,732 bulbs.

Central Station Electricity

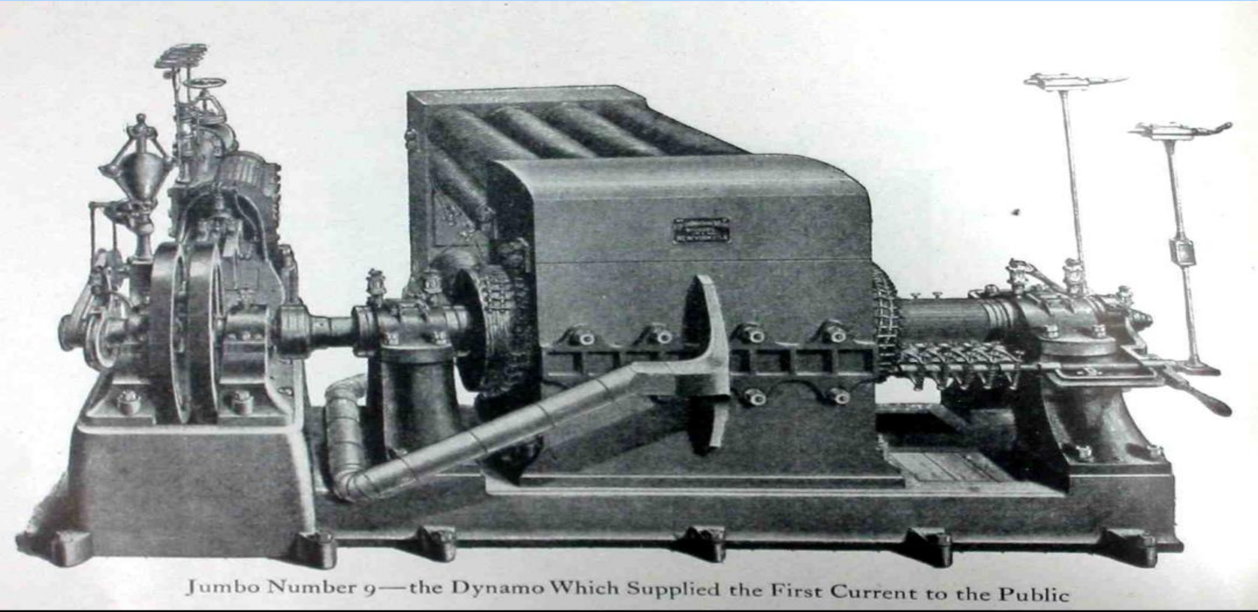
- 1882 Edison’s first electric light generating plant went online
- Initially sold electricity on a per-lamp rate
- This was unsatisfactory so he developed a chemical ampere-hour meter that consisted of a jar holding two zinc plates connected across a shunt in the customer's circuit
- The change in the plates' weight between readings was a measure of electricity consumption





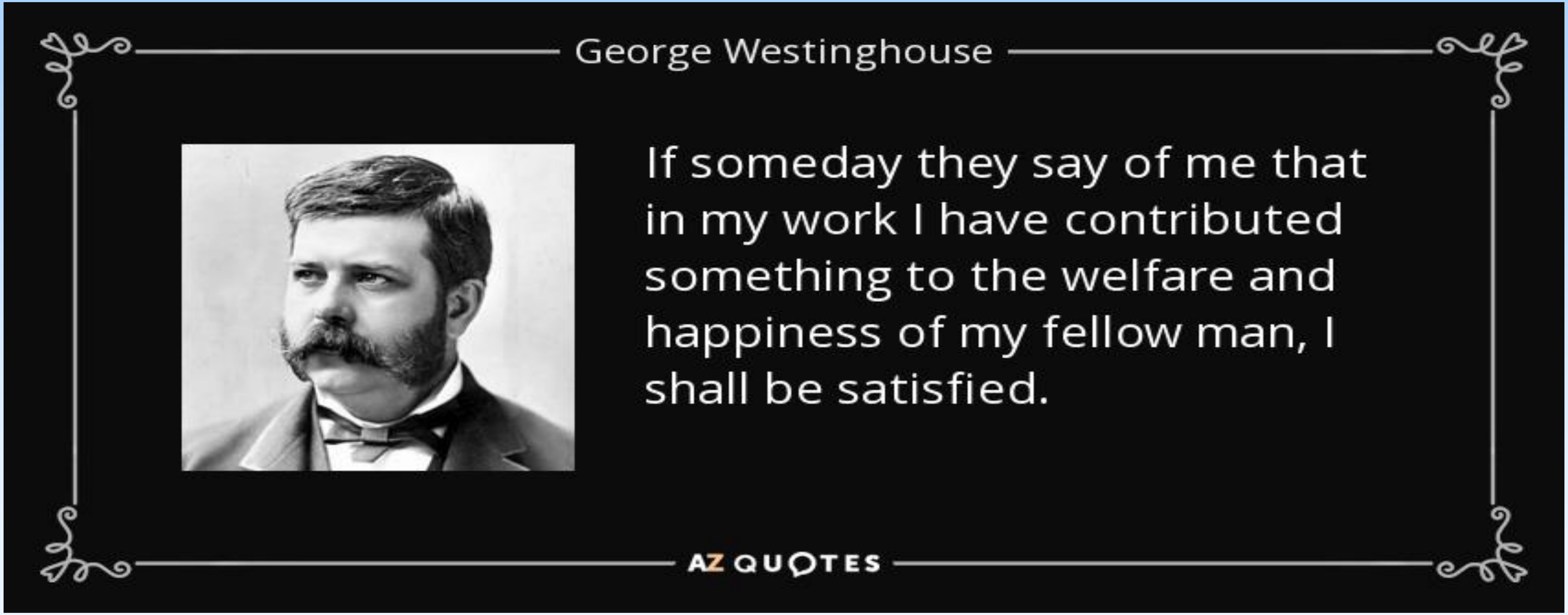
The Problem with Direct Current

- High losses required generators near the loads – maximum of one mile without huge conductors.
- Difficult to change voltages for transmission with DC



Edison's Jumbo Number 9
at Pearl Street in New York City

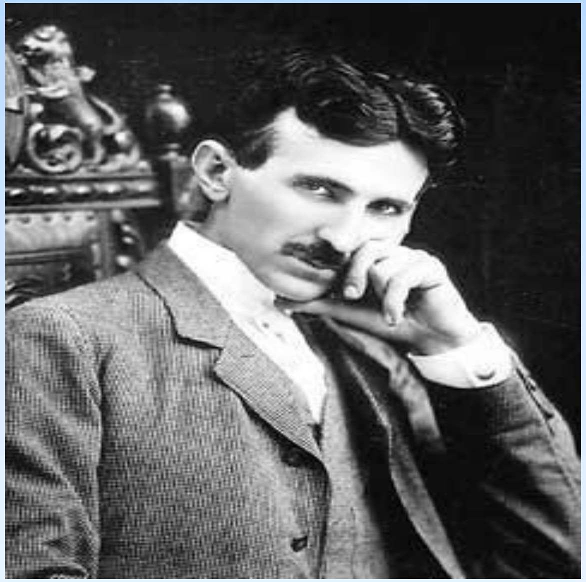
George Westinghouse



1888: A young Serb named Никола Тесла (Nicola Tesla) meets George Westinghouse

Tesla: "The Wizard of The West"

Westinghouse: American entrepreneur and engineer



1882: induction motor

1893 World's Fair Chicago
Lighted by Westinghouse / Tesla

Thomas Edison - 1889

"Fooling around with alternating current is just a waste of time. Nobody will use it, ever."

The Battle of the Currents

- Edison was a shrewd businessman who wanted to profit from his inventions.
- Tesla was a brilliant scientist but not a good businessman.
- Edison took advantage of Tesla’s technical skills without compensating him.
- Westinghouse treated Tesla with respect and funded his experiments in AC power.
- Edison lobbied for AC power to be used in executions and then claimed AC was “too dangerous”.

1893: Westinghouse awarded the contract for powerhouse at Niagara Falls

Edward Dean Adams power station at Niagara, with ten 5,000 horsepower Tesla/Westinghouse AC generators—the culmination of Tesla's dream.
(Courtesy Smithsonian Institution)

Types of Early Electric Meters

- *Electrolytic Meters* are exclusively ampere-hour meters.
  - Chemical cells measure electricity by change of weight of cell plates.
- *Motor* Meters
  - Typically ampere-hour meters. AC or DC electric motor.
- *Intermittent Registering Meters*
  - Some form of ampere-meter or watt-meter registers the current or power passing into the house;
  - A clock makes periodic readings of the ampere-meter or watt-meter and adds to a mechanical register
- *Induction Meters* – AC only. Predecessors of modern electricity meters

Galileo Ferraris

- Tesla in 1882 identified concept of rotating magnetic field
- Dr. Ferraris, in 1885, proved that torque could be produced electromagnetically by two alternating-current fluxes, which have a time displacement and a space displacement in the direction of proposed motion.

1893 Nikola Tesla Induction Motor Patent

- Nikola Tesla takes out a patent covering Ferraris' discovery of the induction motor principle.
- There was a brief patent infringement suit, but Tesla was awarded priority. This was just one of Tesla's many patents later purchased by George Westinghouse.

Elihu Thomson

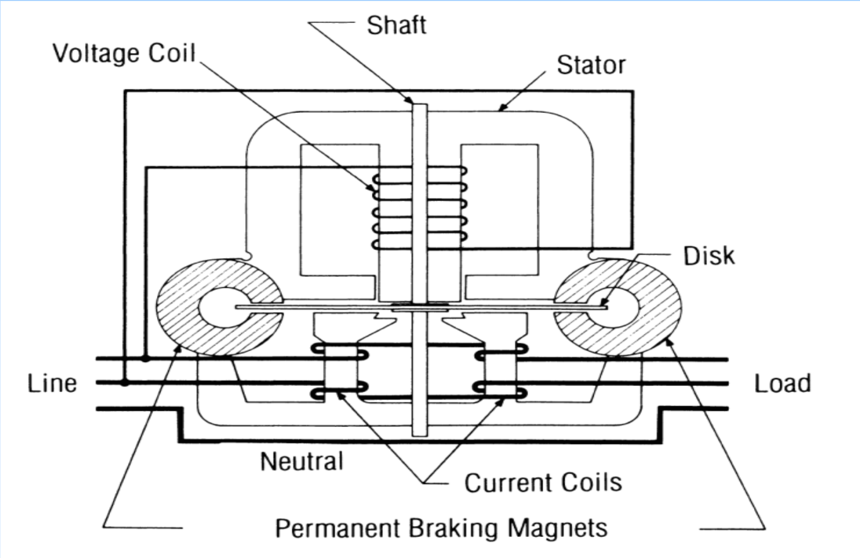
- 1889 Thomson introduced his recording wattmeter (AC or DC – a commutator-type meter).
- This was the first true watthour meter, and it was an immediate commercial success, many utilities adopting it as their "standard" model.
- Although this meter was initially designed for use on AC circuits, it worked equally well with the DC circuits in use at the time.
- The introduction and rapid acceptance of induction-type watthour meters in the late 1890s relegated the use of this commutator-type meter to DC circuits.

Induction Watthour Meter

- 1892 Thomas Duncan develops the first induction watthour meter to use a single disk for both the driving and braking element but the design never went into production.
- 1894: With the rapid growth of the electric industry at this time, AC was now being used to run motors, and the existing ampere-hour meters and commutator-type watthour meters were unable to take into account varying voltages and low power factors on AC circuits.
- Several inventors worked to develop a new meter to meet this need, but Shallenberger hit on the most workable approach - a small induction motor with the voltage and current coils 90 degrees out of phase with each other.
- This concept was refined into the first commercially produced induction watthour meter. This model was one of the heaviest ever offered at 41 pounds and one of the most expensive of its time.

Induction Meters

- Using concepts put forth by Tesla and Ferraris, several inventors created early induction watthour meters
- Two coils and a conducting (usually aluminum) disk. A braking magnet.
- Magnetic field from the first coil generates *eddy currents* in the disk
- Magnetic field from the second coil interacts with the eddy currents to cause motion
- Disk would accelerate without bound except for eddy currents caused by motion through fixed magnetic field which slows the disk
- The end result is that each revolution of the disk measures a constant amount of energy



Basic Energy Formula

- The essential specification of a watthour meter's measurement is given by the value
  K_h [Watthours per disk revolution]

- The watthour meter formula is as follows:

$$E\,[\textbf{Watthours}] = K_h\left[\frac{\textbf{watthours}}{\textbf{disk revolution}}\right] * n[\textbf{disk revolutions}]$$

1893: Blondel's Theorem

- The theory of polyphase watthour metering was first set forth on a scientific basis in 1893 by Andre E. Blondel, engineer and mathematician. His theorem applies to the measurement of real power in a polyphase system of any number of wires. The theorem is as follows:
  - If energy is supplied to any system of conductors through N wires, the total power in the system is given by the algebraic sum of the readings of N wattmeters, so arranged that each of the N wires contains one current coil, the corresponding voltage coil being connected between that wire and some common point. If this common point is on one of the N wires, the measurement may be made by the use of N-1 wattmeters.

Standing on the Shoulders of Giants

A History of the EEI and AEIC Meter Committee Work

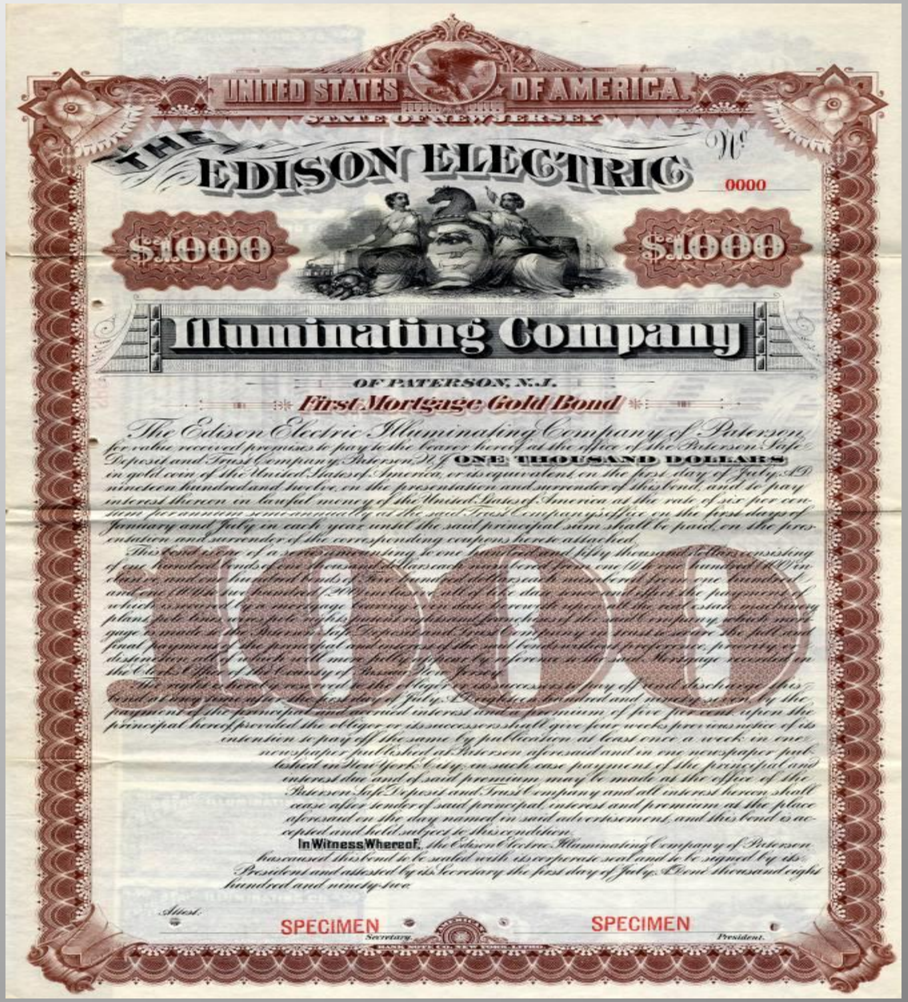
“If I am able to see further, it is only by standing on the shoulders of giants” – Sir Isaac Newton

National Electric Light Association

- Formed in 1885
- J. Frank Morrison, Brush Company of Baltimore Baltimore, MD 1st President
- Held at the Grand Pacific Hotel
- Vendor Dominated
- One Operating Committee

Association of Edison Illuminating Companies

- AEIC was formed in 1885
- James S. Humbird of Cumberland, MD, First President
- Held in Harrisburg, PA at Harrisburg Edison Electric Light Co.
- Only Edison Franchisees and Guests Were Invited to First Meeting

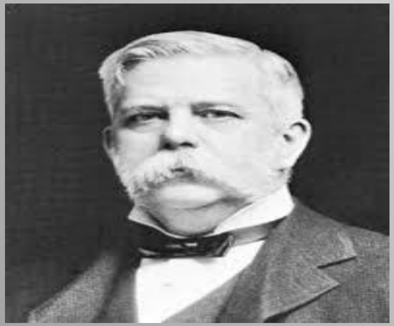


NELA vs. AEIC

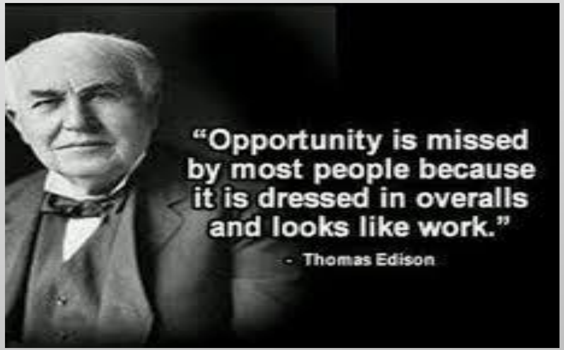
- Large Flashy Industry Meetings
- Objective was to promote Lighting Manufacturers, Apparatus Integration, and Systems Construction
- Focused On Arc-Lighting Systems Promotion
- Prioritized Expansion of Electric Systems, Regardless of AC or DC

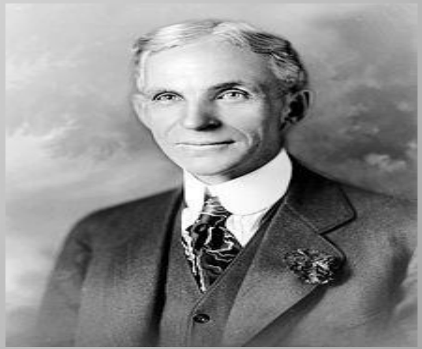
- Small, Focused Utility Group Meetings
- 1885 By-Laws - Objectives: “Mutual Protection of (Electric System) Owner Interests; Thoughtful Information Collection and Dissemination”
- Focused on Incandescent Lighting Promotion
- Prioritized Standardization of electrical Systems

Meeting Attendance

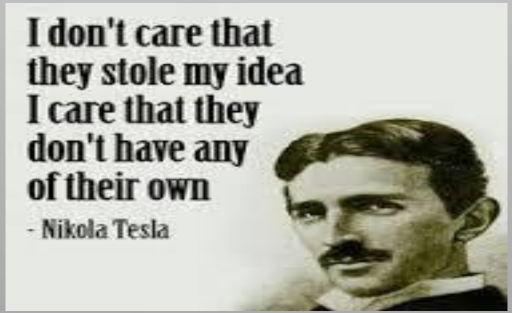


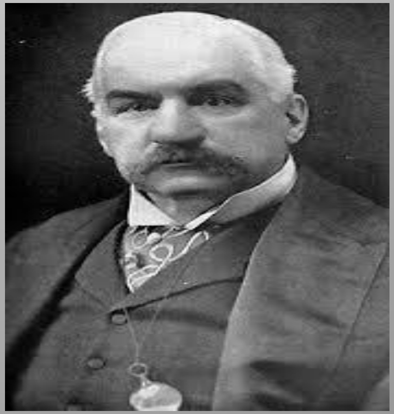
Lord Stanley





Thomson-Houston





AEIC Meter Committee

- The Issue of metering was discussed as early as 1887 as part of the formal meeting.
- The AEIC Committee On Meters was first discussed in 1896
- The committee was established in 1898, With Alex Dow, Edison Illuminating company of Detroit, Presiding as Chair.
- About Alex Dow….

Early AEIC Meter Committee Activity

- The Wright vs. Barstow Debate
- Emerging Technologies
- Research and Development
- The Great Dial Debate
- Pre-Paid Metering
- Battery Storage Implications

The Rise of the NELA Meter Committee

- NELA Meter Committee Established in 1908, With Alex Dow, Edison Illuminating Company of Detroit, Presiding
- Samuel Insull had great influence on both the formation of the Committee and the topics covered
- The first committee had many AEIC Members besides Dow, Including John Lieb (NY), Louis Ferguson (IL), and Charles Edgar (MA).

Publishing The First Works

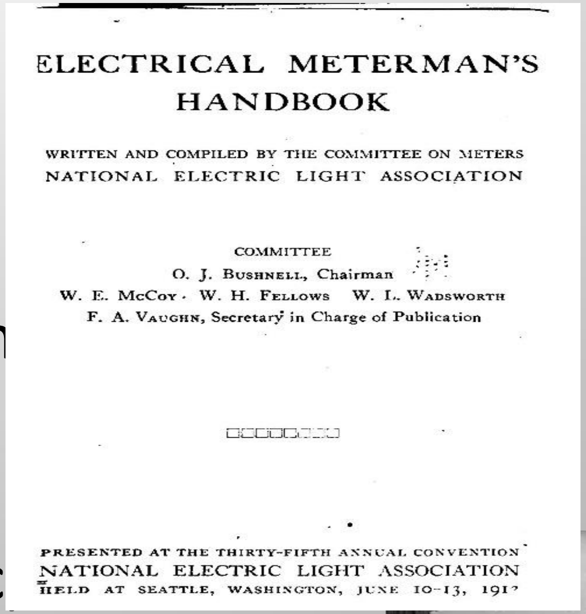
- Beginning in 1897, NELA put a focus on developing the first edition of the National Electric Code
- Beginning in 1902, AEIC began work on collecting requirements from member companies for meter standardization
- By 1908, the AEIC Committee began work on the Code for Electricity Meters

The Coming Together

- The AEIC and NELA Metering Committee first Met in 1910 at the Hotel Frontenac in Thousand Islands, NY
- They met for the historic publishing of the AEIC Code For Electricity Meters – The predecessor to ANSI C12
- It was deemed in 1910 that all future work on the Code for Electricity Meters shall be collaborative between NELA and AEIC

The “Handbook”

- Based on the work of the AEIC Code, NELA Members began work on the first “Electric Meterman’s Handbook”
- Presented at the Historic Hotel Washington in Seattle, WA
- The NELA/AEIC Joint Presentation also Featured Vendors: Thomson (General Electric Westinghouse, Fort Wayne, Sangamo, Duncan Columbia, The Eastern Specialty Company, Cutler-Hammer, Biddle, Leeds & Northrup and The States Company



ELECTRICAL METERMAN’S
HANDBOOK

WRITTEN AND COMPILED BY THE COMMITTEE ON METERS
NATIONAL ELECTRIC LIGHT ASSOCIATION

COMMITTEE
O. J. BUSHNELL, Chairman
W. E. McCOY · W. H. FELLOWS W. L. WADSWORTH
F. A. VAUGHN, Secretary in Charge of Publication

PRESENTED AT THE THIRTY-FIFTH ANNUAL CONVENTION
NATIONAL ELECTRIC LIGHT ASSOCIATION
HELD AT SEATTLE, WASHINGTON, JUNE 10–13, 1912

The Depression

- NELA Was Disbanded in 1932 after Congressional Investigations
- Samuel Insull Disgraced as leader of NELA and faced multiple federal charges, PUCHA was instituted as a result
- Edison Electric Institute was created in 1933 to continue the policy work of NELA
- NELA Committee Works continued under EEI

Up and Away

- Since 1910, The AIEC and EEI Meter Committees have met at least annually until this date
- Through the years, the objectives of the committees has remained largely the same – producing high quality products for industry use while creating a platform to share knowledge and experiences

1895 – 1990 Highlights

- 1920’s Overload and temperature compensation
- 1934 Standardized Socket (“S”) meters introduced.
- 1930’s Laminated disks allow multi-element meters with minimal interaction between elements.
- 1948 Magnetic suspension bearings
- 1960 All manufacturers use magnetic suspension bearings

1895 – 1990 Summary

- Refinement of the basic induction watthour meter, with variations in the rotor design (disk vs. cup-shaped) improvements in bearing technology, improvements in magnet technology, and the realignment of multiple inventors and meter manufacturers.
- 1970’s saw the introduction of electronics, first into registers and later for metrology, eventually displacing the electromechanical meter by 2006.

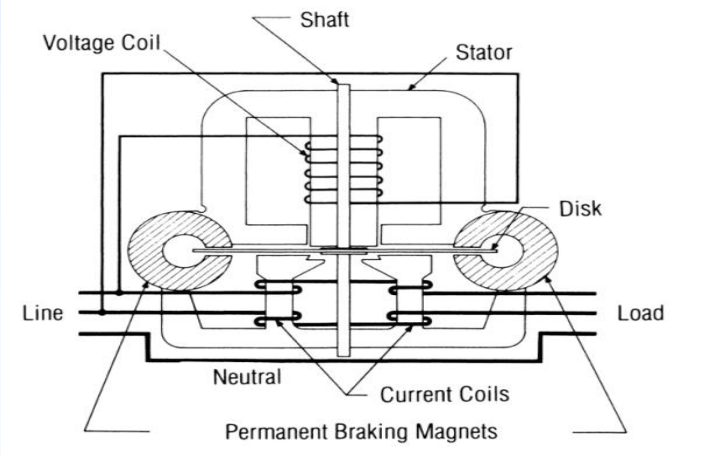
History - Conclusions

- The basic measurement apparatus for the electric power industry has a long and rich history, with electromechanical devices being normative for more than 100 years.
- We are embarking on a new era with microelectronics displacing electromechanical meters.
- The next 100 years will be interesting……

Capabilities and Opportunities for Emerging Electronic Meters

Electromechanical Devices

- Limited to fundamental functions by the physics of the instrument
  - Volts – Average, RMS
  - Amps – Average, RMS
  - Watts, Reactive Watts - Var (using phase shifted voltage)
  - Integrated quantities:
    - Watthours
    - Varhours



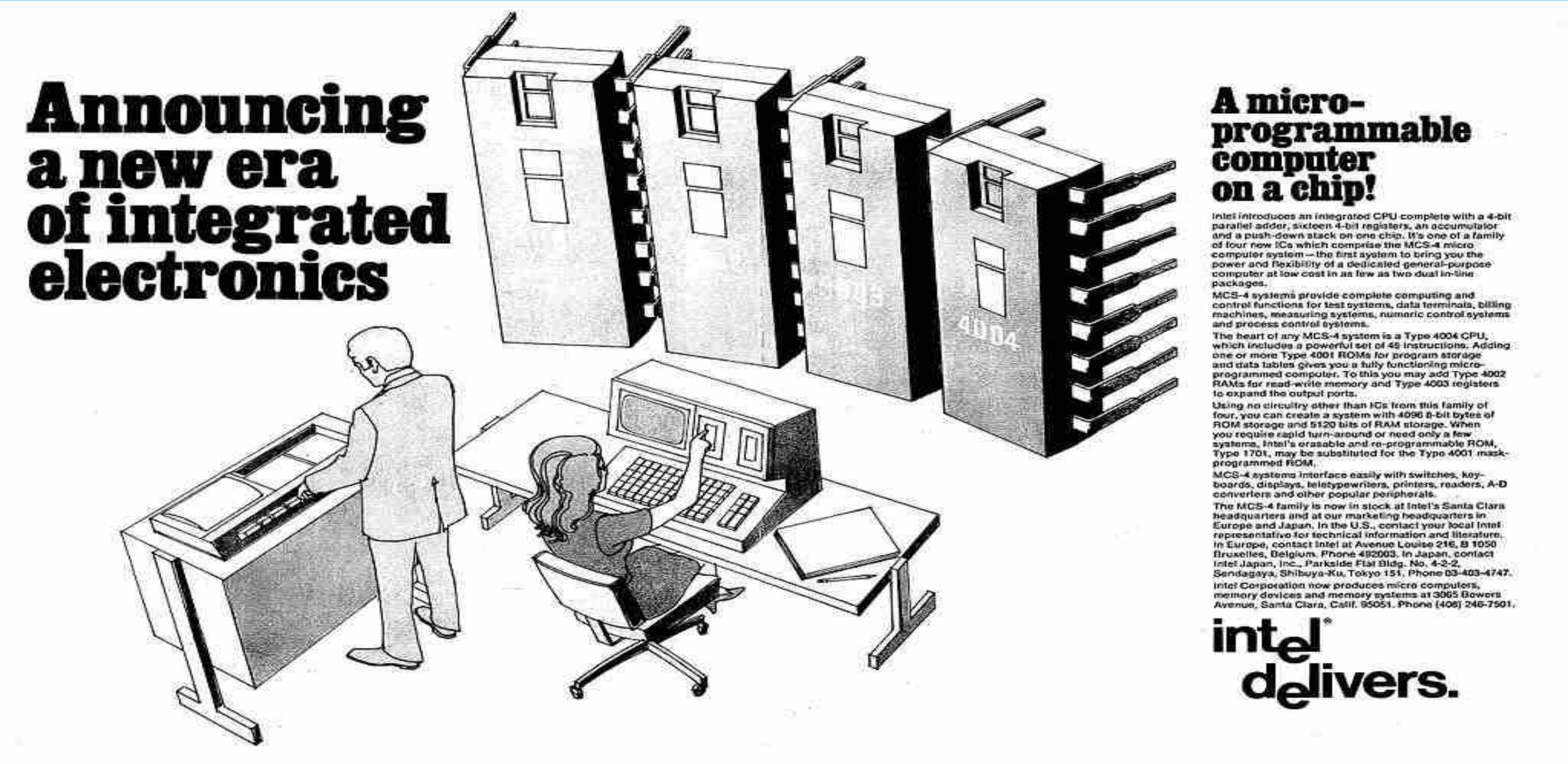
Electronic Registers on Electromechanical Measurement

- **Still only a single quantity because of limitations of rotating disk element.**
  - **But now could accumulate energy “pulses” internal to the meter and could support remote communication.**
  - **Could easily handle multiple “buckets” for time-of-use registration**
  - **Could more efficiently calculate demand quantities**

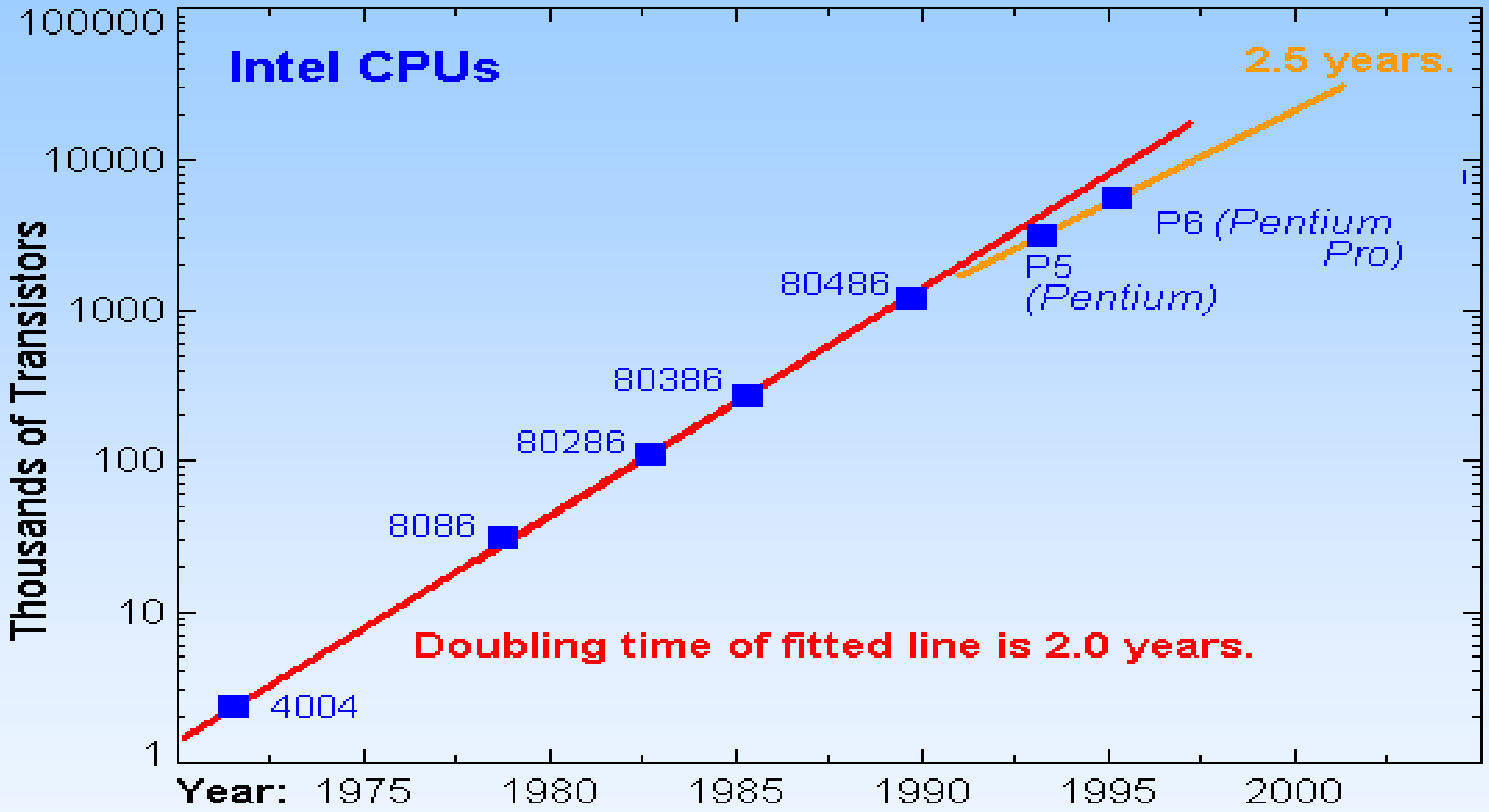
Emerging Designs

- **Early all-electronic meter metrology was designed by the traditional electromechanical meter designers**
- **Now highly integrated microprocessor chips include built-in metrology capability**
- **Higher speeds and more memory support many new functions……**

November 15, 1971:
Intel MCS-4 (4004) announced

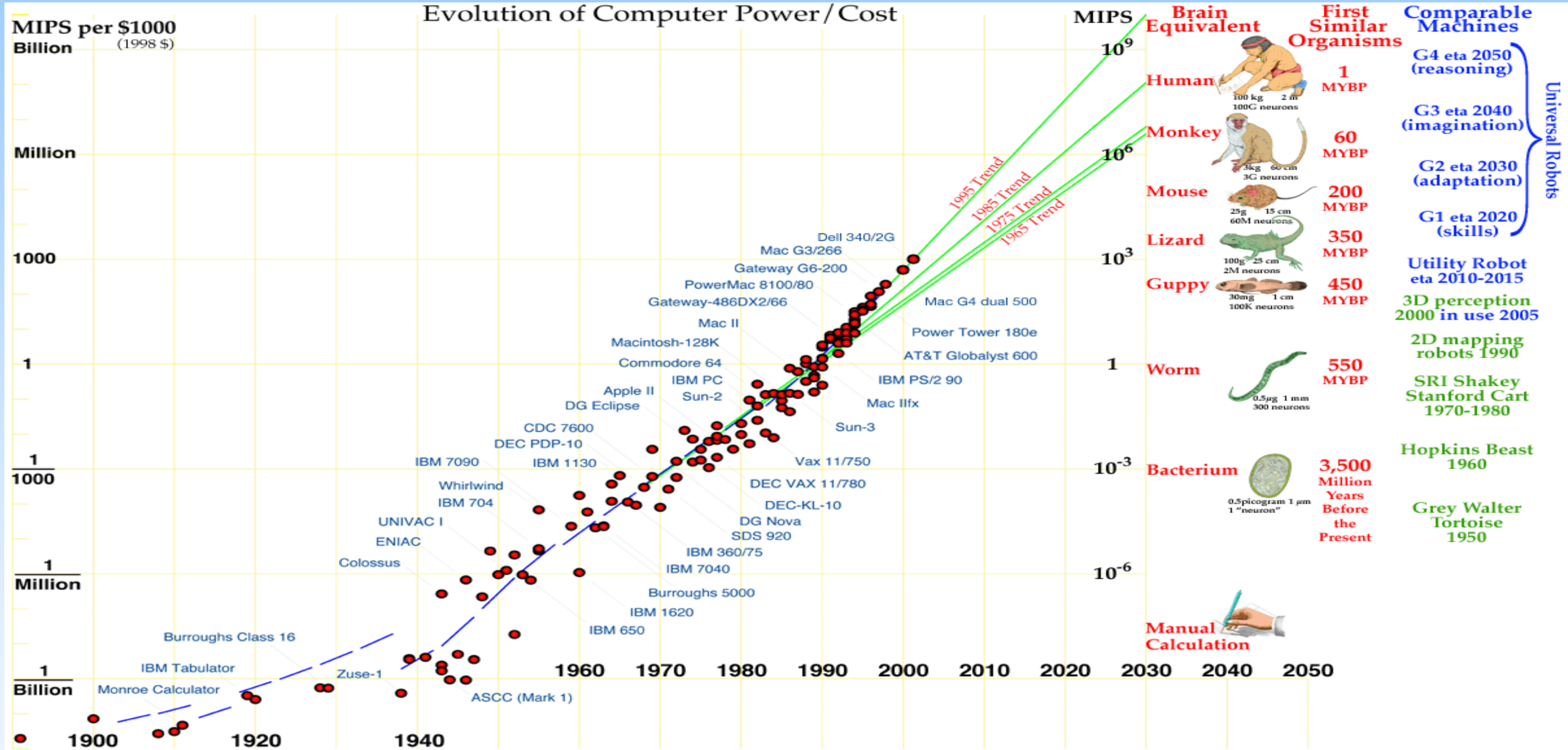


Processor Complexity Over Time



Source: http://www.physics.udel.edu/~watson/scen103/intel-new.gif

Processor Cost Goes Down While Ability Goes Up



Source: https://www.eitdigital.eu/uploads/pics/computer-power-future.gif

Microprocessor-Powered Meters

- First microprocessor – Intel 4004 (November 15, 1971)
- Today's microprocessors millions of times faster than 4004
- Technical capabilities undreamed of in the days of electromechanical measuring devices
- Let's look at the possibilities…..

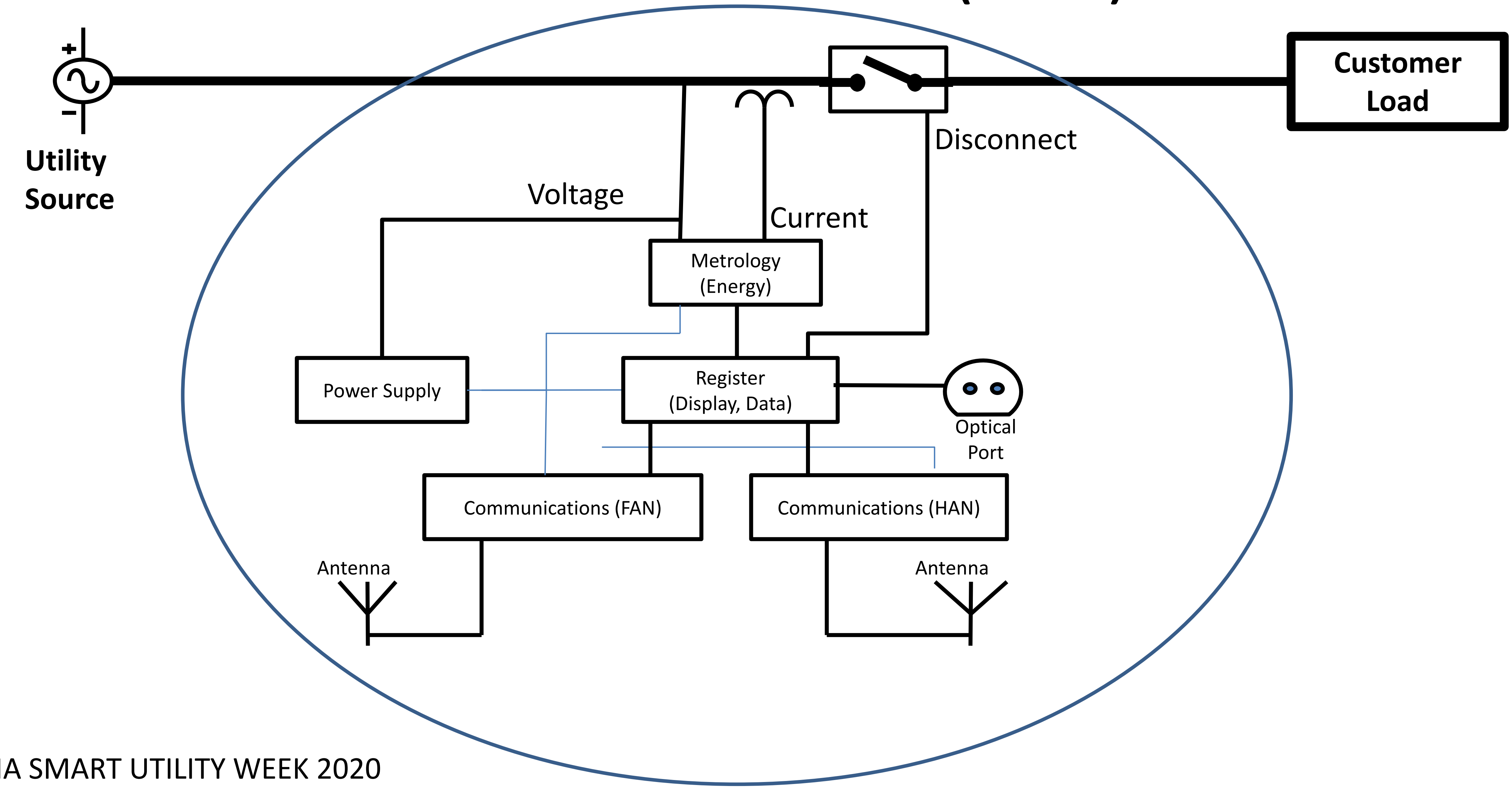
Microprocessors

- The introduction of the Intel 4004 microprocessor in 1971 started a revolution in distributed processing
  - Initially introduced to add features to the register function (adding a rich variety of recording and display options)
  - Early microprocessors did not have sufficient reliability or computational horsepower to perform the metrology function
  - Early microprocessor designs were limited in the computational horsepower necessary for advanced features such as Power Quality and Harmonics measurements

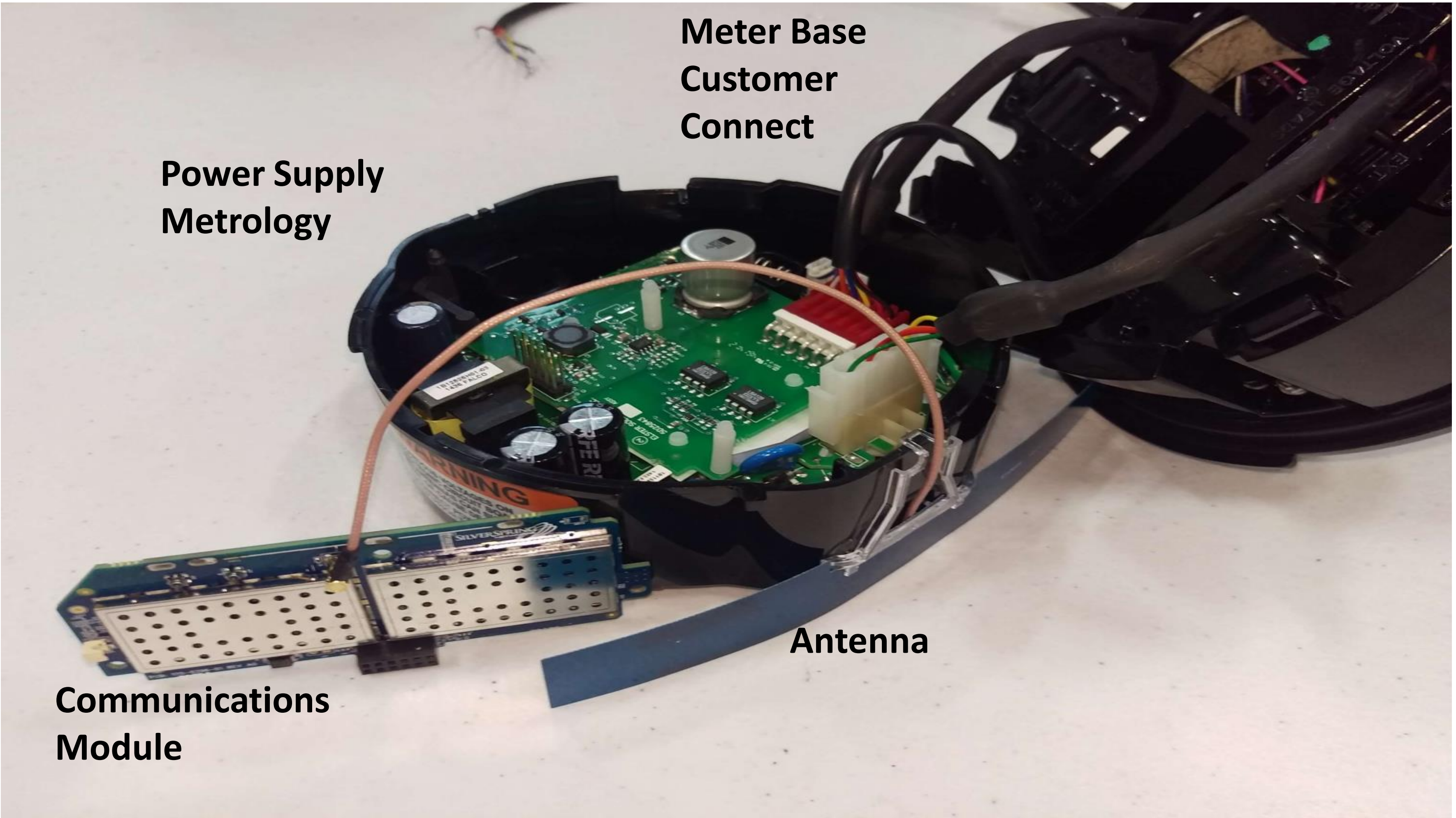
Microprocessors (continued)

- Special-purpose electronic engines were introduced such as the Itron Centron meter which uses Hall-effect current sensing and an Application Specific Integrated Circuit (ASIC) for computation.
- Other manufacturers used special-purpose metrology circuits for the metrology function.
- These designs allowed a single metrology device to simultaneously measure both real and reactive power.
- Has now grown to the point that the microprocessor does a better and more efficient job of the basic measurement function than was possible with electromechanical meters.

Electronic Meter (AMI)



Typical Meter Breakdown



Advanced Features

- More options for interval data recording
- More options for TOU and Demand bins
- Power quality and harmonic analysis
- Built-in whole-service disconnect
- Distributed-intelligence “edge analytics”
  - Hot socket detect and reporting
  - Load disaggregation
  - Open neutral detect
  - Feeder Phase identification
  - Transformer loading
  - Outage detection and reporting
  - Field intelligence for outage restoration

Why Distributed Intelligence?

Grid operations and stability

Transform consumer relationships

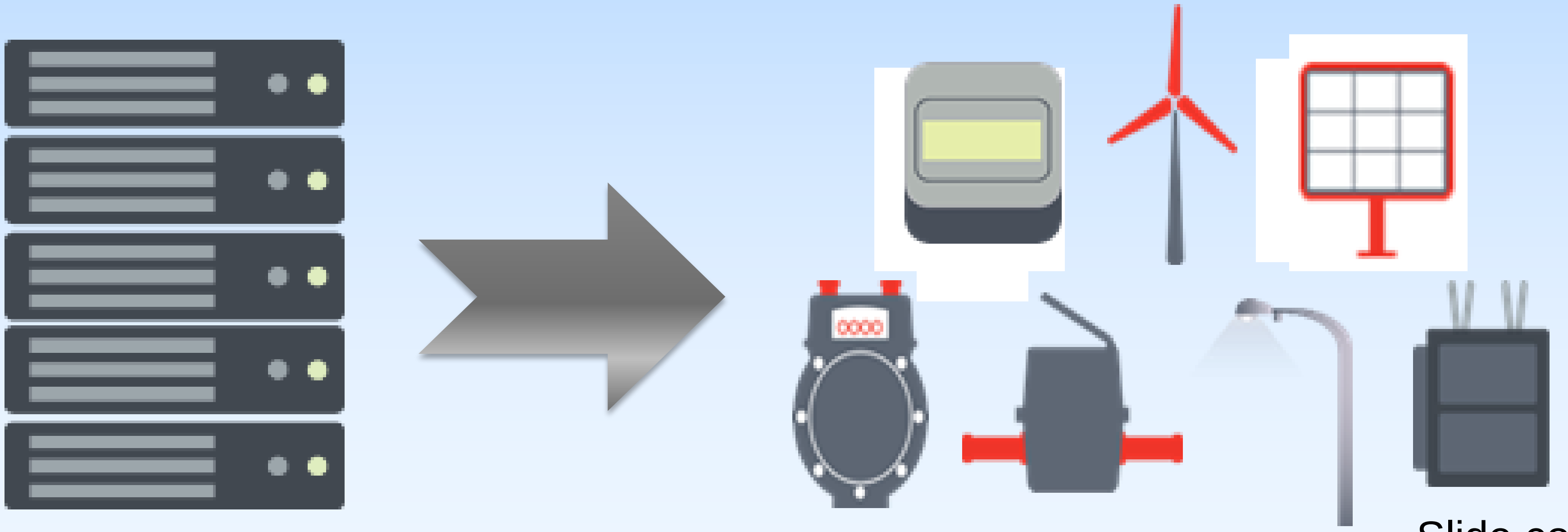
Grid safety and efficiency

Slide courtesy of Itron

Distributed Intelligence

… distribution of *analytics* to the edge

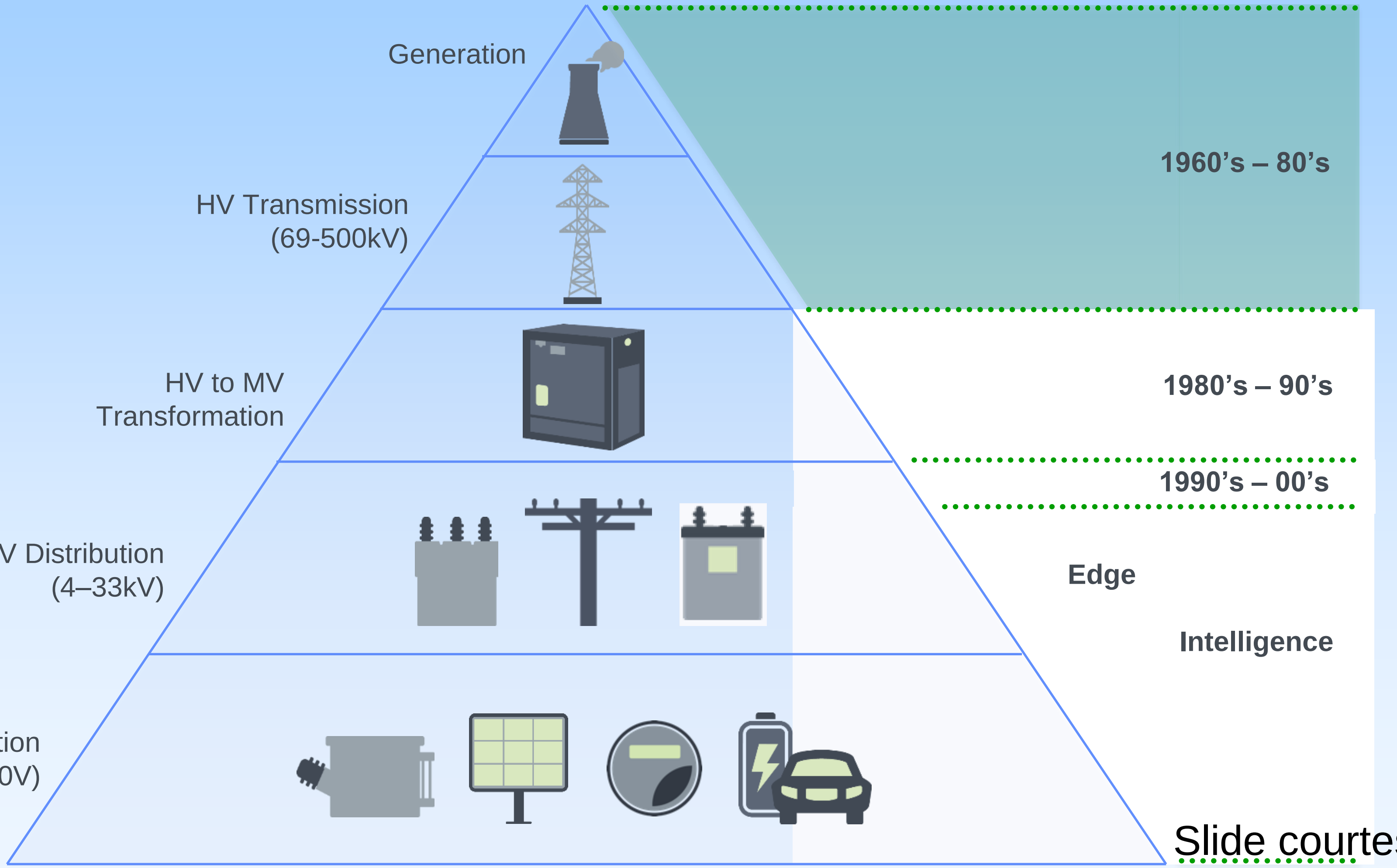
- analysis
- decision making
- action



Slide courtesy of Itron

DISTRIBUTED INTELLIGENCE

Operational awareness and action to the edge of the distribution grid



Slide courtesy of Itron

How is this possible?

Linux computer in every meter	Application platform for distributed intelligence	Local access to high resolution data
Peer-to-peer communications among meters and devices	Open-standards multi-service IPv6 network	Multiple simultaneous network media (RF, PLC, Wi-Fi)

Slide courtesy of Itron

Distributed Intelligence Apps

Grid

- Location Awareness
- High Impedance Detection
- Broken Neutral Detection
- Active Transformer Load Management
- Feeder Phase Balancing
- Outage Detection
- Cold Load Pickup
- Active Voltage Management
- Bypass Theft Detection
- Secondary Service Theft Detection

Consumer

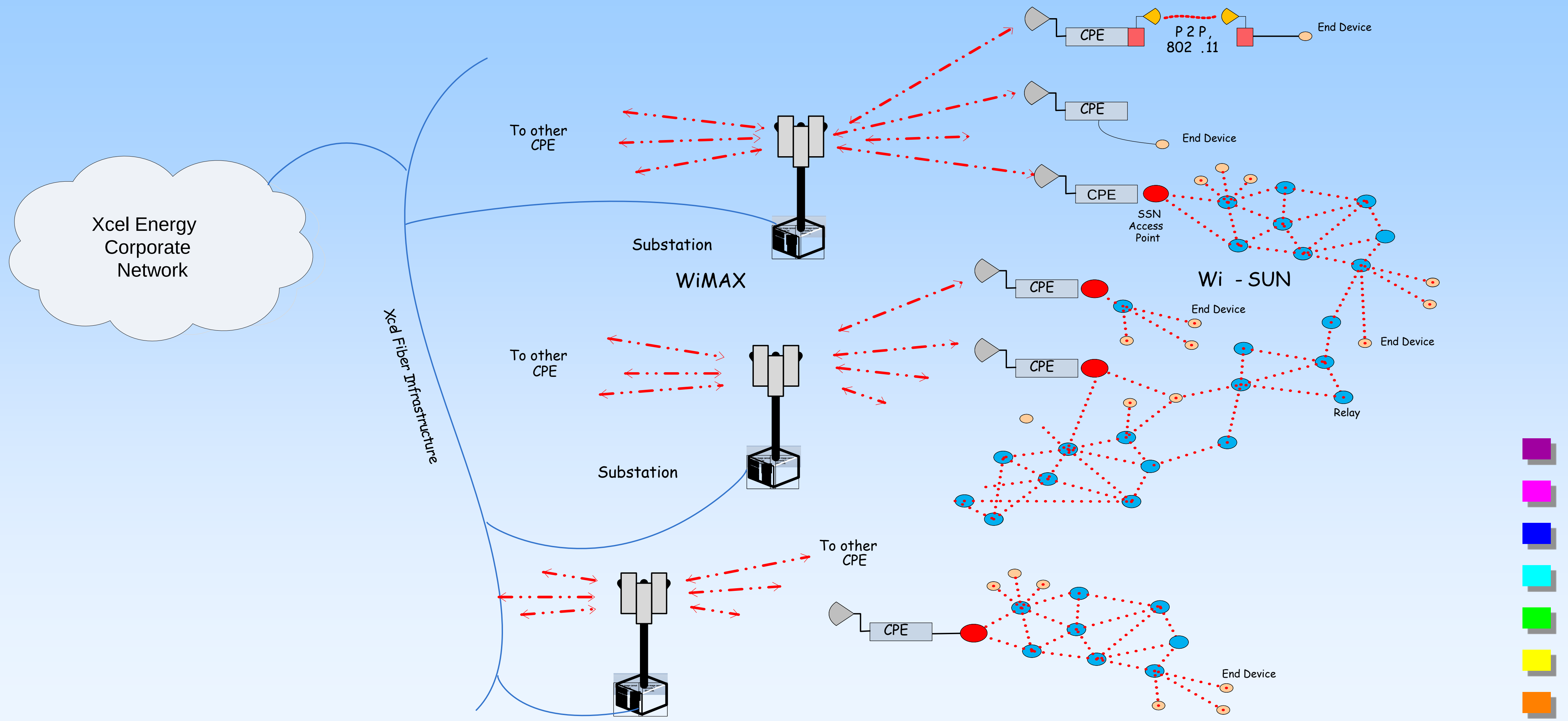
- Load Disaggregation
- Excess Usage Identification
- Activity in the Home
- TOU/Peak Alerts
- Targeted Marketing
- EV Identification

DER

- Active Demand Response
- DG Detection
- Solar Identification
- Solar Disaggregation and Forecasting
- Real Time Markets

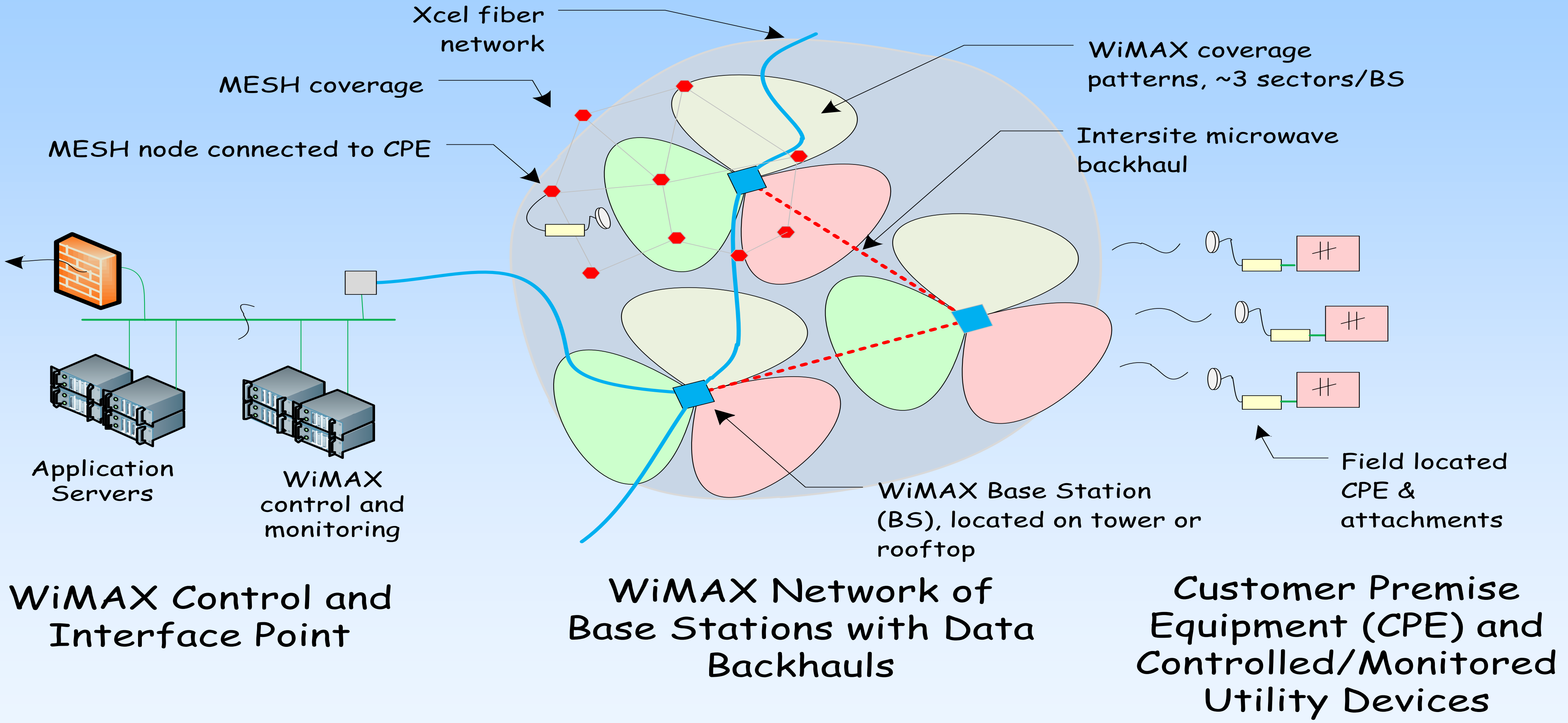
Slide courtesy of Itron

Communication Capabilities



CPE
P 2 P, 802 .11
End Device
To other CPE
CPE
End Device
CPE
SSN Access Point
Xcel Energy Corporate Network
Substation
WiMAX
Wi - SUN
CPE
End Device
Xcel Fiber Infrastructure
To other CPE
CPE
End Device
Relay
Substation
To other CPE
CPE
End Device

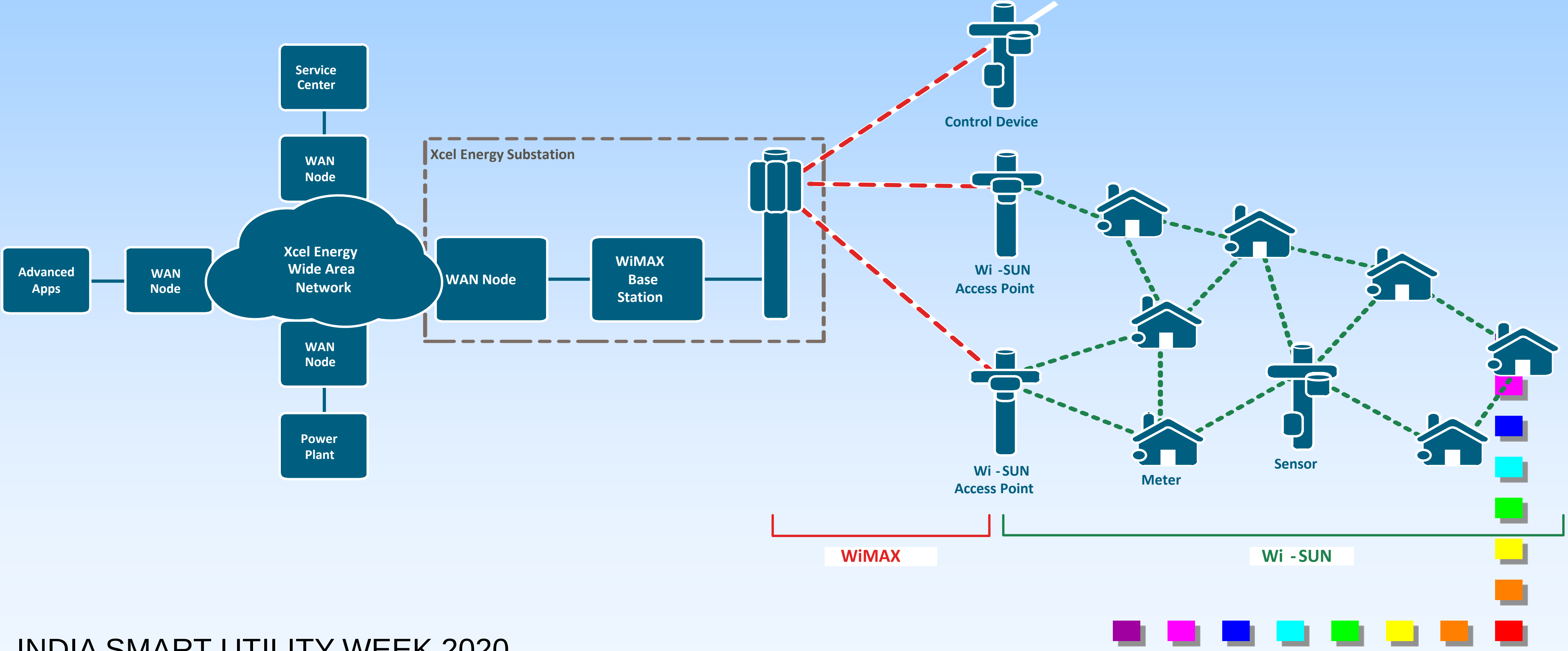
Typical Configuration for a WiMAX / Wi-SUN Network



Summary

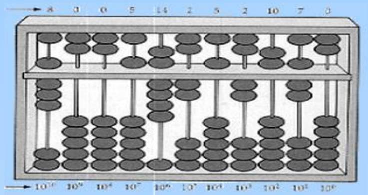
- Today's highly-integrated microprocessor-based meters give unprecedented capability for:
  - Advanced metrology capability
  - Direct participation in "Smart Grid" functions
  - Interaction with customer "Internet of Things" devices
  - Edge computing for Load Disaggregation, Hot Socket Detection, Feeder Phase Detection, and much more.

Field Area Network (FAN) Overview



A Glimpse at the Future of Electricity Metering

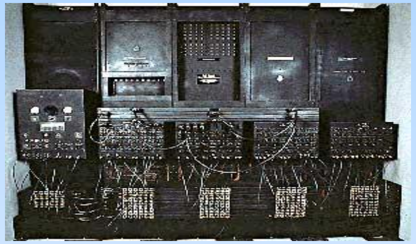
Early Computing

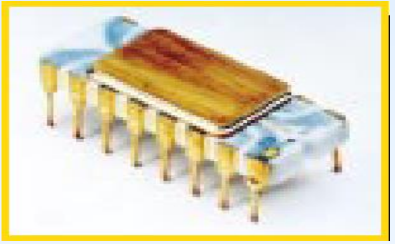


- 3000 BC - Abacus (Babylonia)
- 1612: Decimal Point (John Napier)
- 1622: Slide Rule (William Oughtred)
- 1642: Adding Machine (Blaise Pascal)
- 1888: Difference Engine (Charles Babbage)
    - “The Father of Computing”
- 1911: “Computing-Tabulating-Recording Company” (CTR) founded – design and manufacture punched-card tabulating machines
- 1924: CTR renamed the “International Business Machines Corporation” (IBM)

Early Digital Computers

- 1939: First relay-logic electromechanical digital computer.
    - A year later it was controlled over phone lines – the first computer networking
- 1943: First vacuum-tube computer
- 1947: Invention of the transistor
- 1948: First stored-program computer
- 1951: First compiler (Grace Hopper)
- 1953: IBM 650 – first mass-produced computer
- 1958: MODEM introduced
- 1958: Digital Equipment Corporation (DEC) founded
- 1959: GE Introduces computer for banking application
- 1964: IBM introduces the System/360
- 1964: Control Data introduces first “supercomputer”
- 1964: The Mouse invented
- 1971: The Intel 4004 – first microprocessor
- 1981: IBM PC Introduced

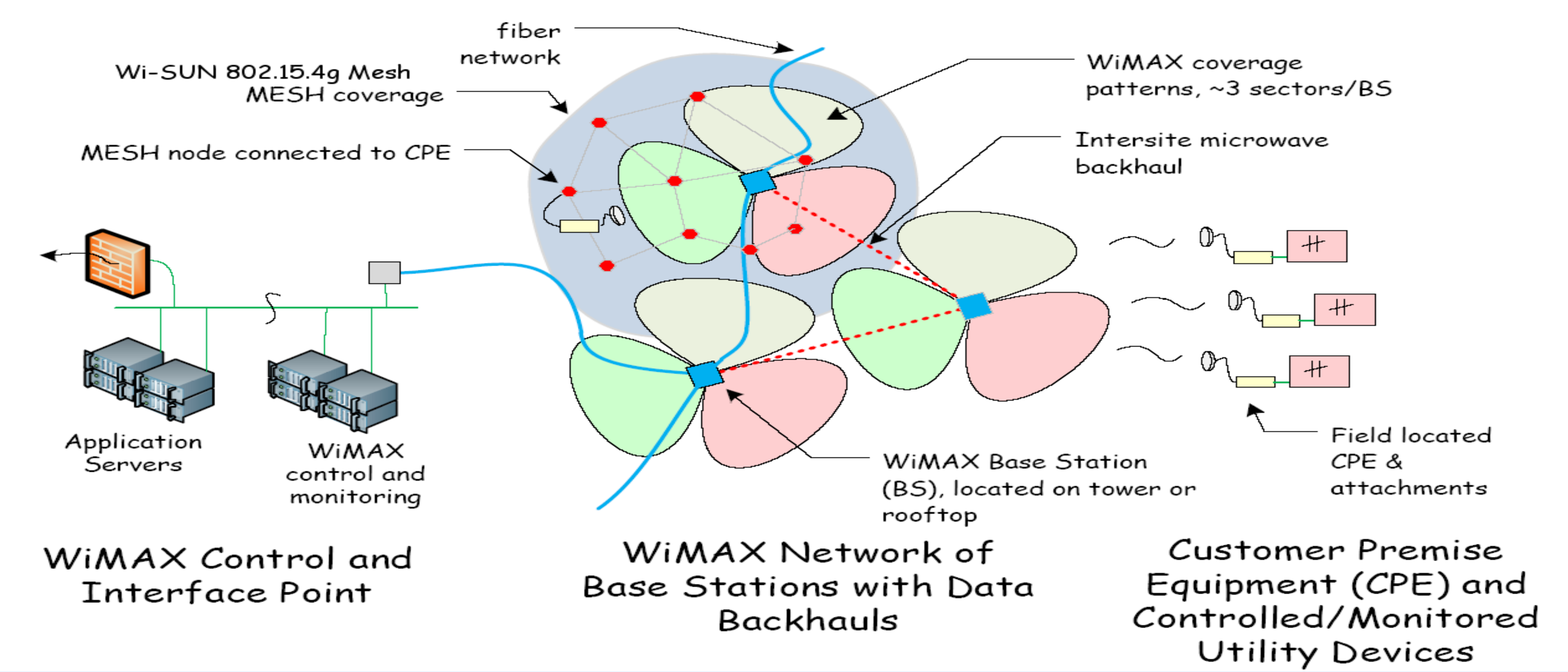




The Microprocessor Revolution

- Microprocessor (Intel 4004 in 1971) opened door for increasing sophistication in meter design that is still continuing today (Fascinating history at http://www.intel4004.com)
- More intelligence could be introduced into the device to increase its functionality
  - Real and Reactive Power
  - Power Quality
  - Demand-Side Management
- Increasingly sophisticated communication techniques

Vision for an Enterprise Network



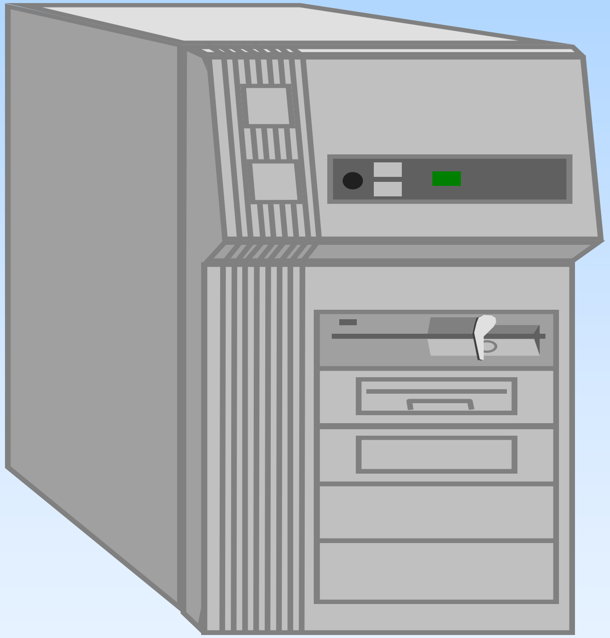
Standards Are Required to Make It Possible

Click here for Standards Presentation:

Achieving_Interoperability_in_Standards_Compliant_World

An analogy: Disk Drive Interfaces

- Originally required proprietary controllers
- Then “standard” interfaces developed, still with manual setup
- Eventually had self-describing drives
- Now we have smart “plug-and-play” operating software



Bottom Line: Lower first cost, faster deployment, more reliable, more flexible

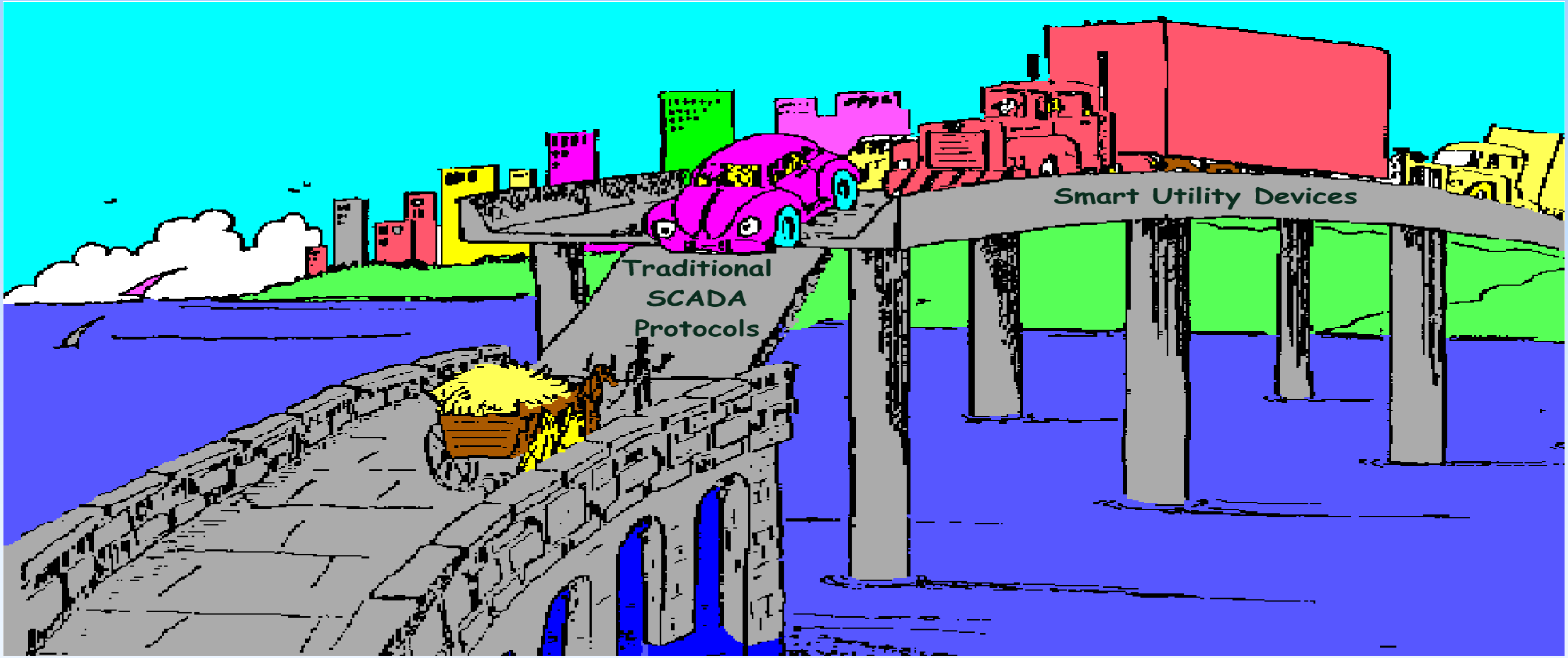
Standards for Electricity Metering

- ANSI:
  - Standard Sockets
  - Standard Performance Tests
  - Standards for Safety
  - Standards for Communications

Meter Standards Still Needed

- Enhanced Safety Standards
- Reactive Power Standards
- Harmonics
- Wireless Mesh Communications
  - Wi-SUN

The Role of Communication Standards for Electricity Metering



Industry Standards Initiatives

- IEEE 802.15.4
  - IEEE 802.15.4, a standardization of wireless specification defined by IEEE, is for wireless personal area networks (WPANs). IEEE 802.15.4 has characteristics such as low power, low cost and peer to peer network support.

IEEE 802.15.4g Smart Utility Networks (SUN)

- IEEE 802.15.4g, also known as the Smart Utility Networks (SUN) standard defines a PHY amendment to IEEE 802.15.4 that facilitates very large scale process control applications such as the utility Smart Grid Networks.
- Wi-SUN Alliance

Standards alone are not sufficient…..

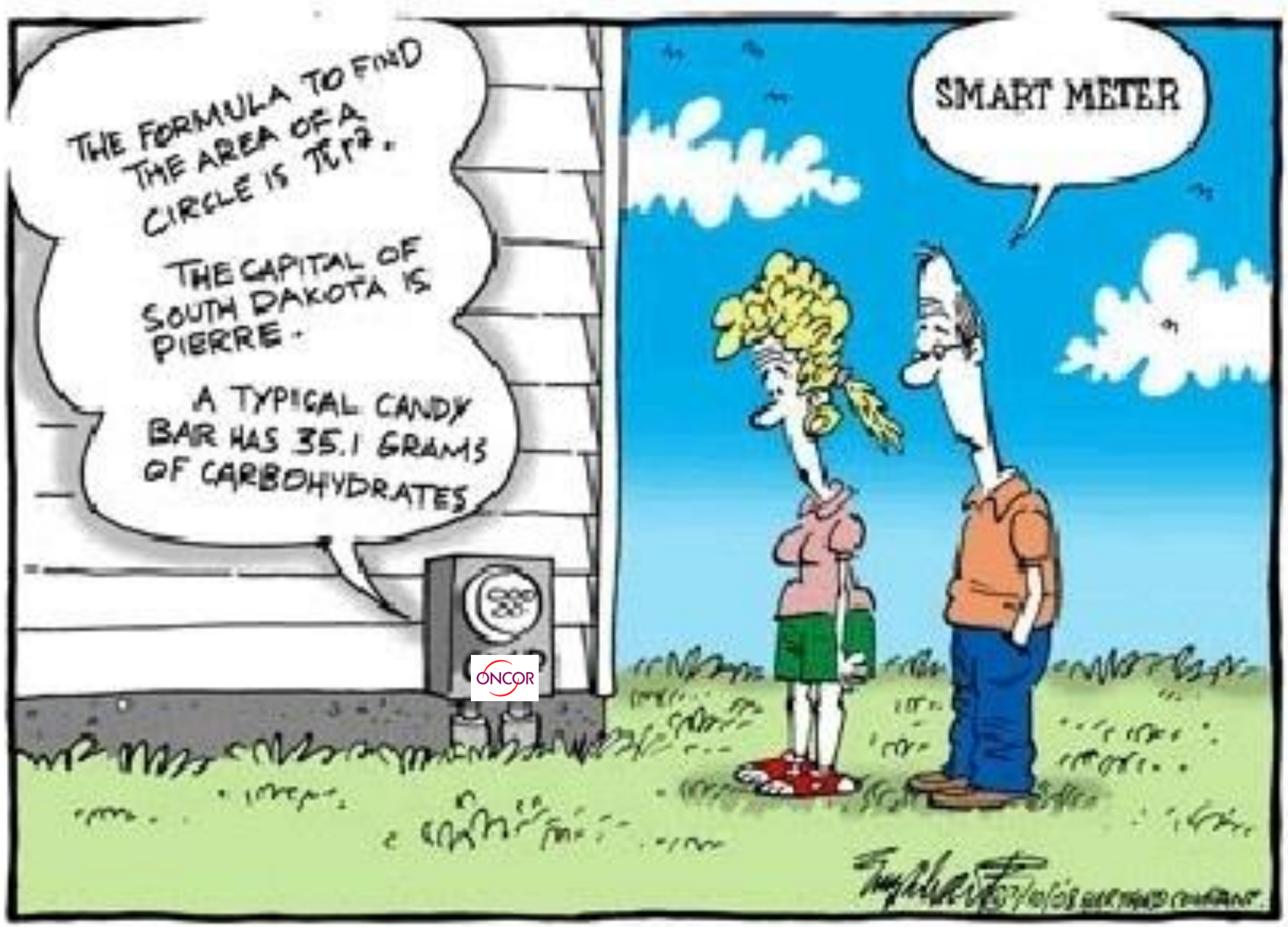
- **Insist on separate implementations that are independently developed and still work together.**
  - Ex: Bar Codes, Wi-Fi, Internet, Internet security (https, etc)
  - Be careful of "standards-compliant" systems that employ innovative but non-interoperable **Security** implementations

Oncor's Advanced Metering System

Credits for AMS material from Oncor Electric Delivery – Dallas, Texas:

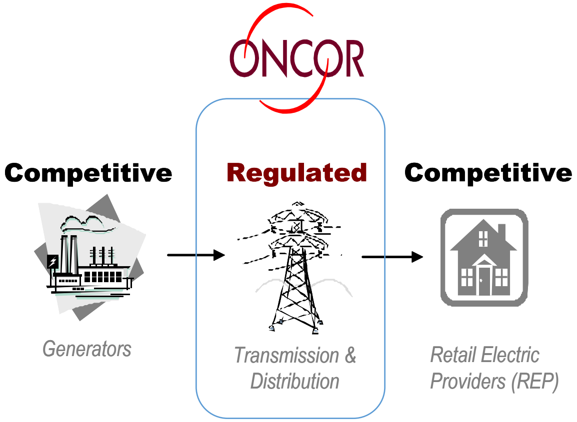
- Jonathan Pettit, PE — Oncor System Metering
- Randall Schmidt — Oncor AMS Operations

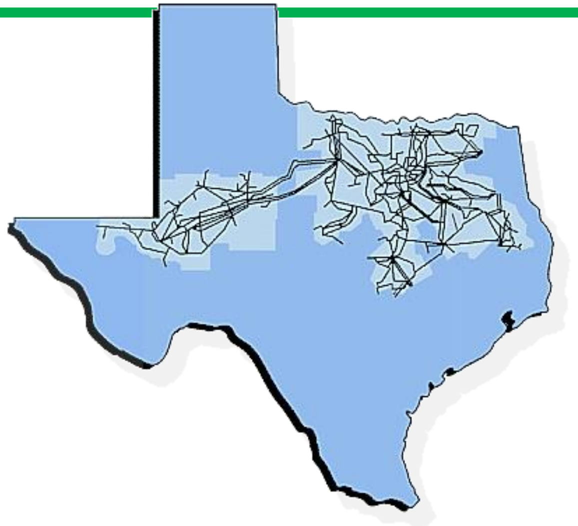
Smart Meters are not…



Size comparison…

Oncor: Who We Are





Our **3,900 employees** serve over **3.6 million meters** - about a third of the state of Texas.

Texas' largest regulated transmission and distribution utility – 6th largest in the US.

AMS Background

"…put information and control into the hands of the consumer, with integrated technologies that enable individuals to obtain timely information on energy use, manage their own consumption patterns and reduce costs." – PUCT

2005

Oncor launches its automated meter reading initiative and begins replacing traditional meters with automated meters.

2007

The Public Utilities Commission of Texas (PUCT) adopts its advanced meter ruling, including specific technical and functional requirements for meters.

Oncor's automated meters are not compliant with the PUC's new regulations and as a result, Oncor revises its *automated* meter reading initiative to become an *advanced* metering system that is PUC-compliant.

2008

The PUC approves Oncor's AMS program filing, including a surcharge to recover implementation costs.

Oncor's AMS initiative evolved as a result of PUCT regulations

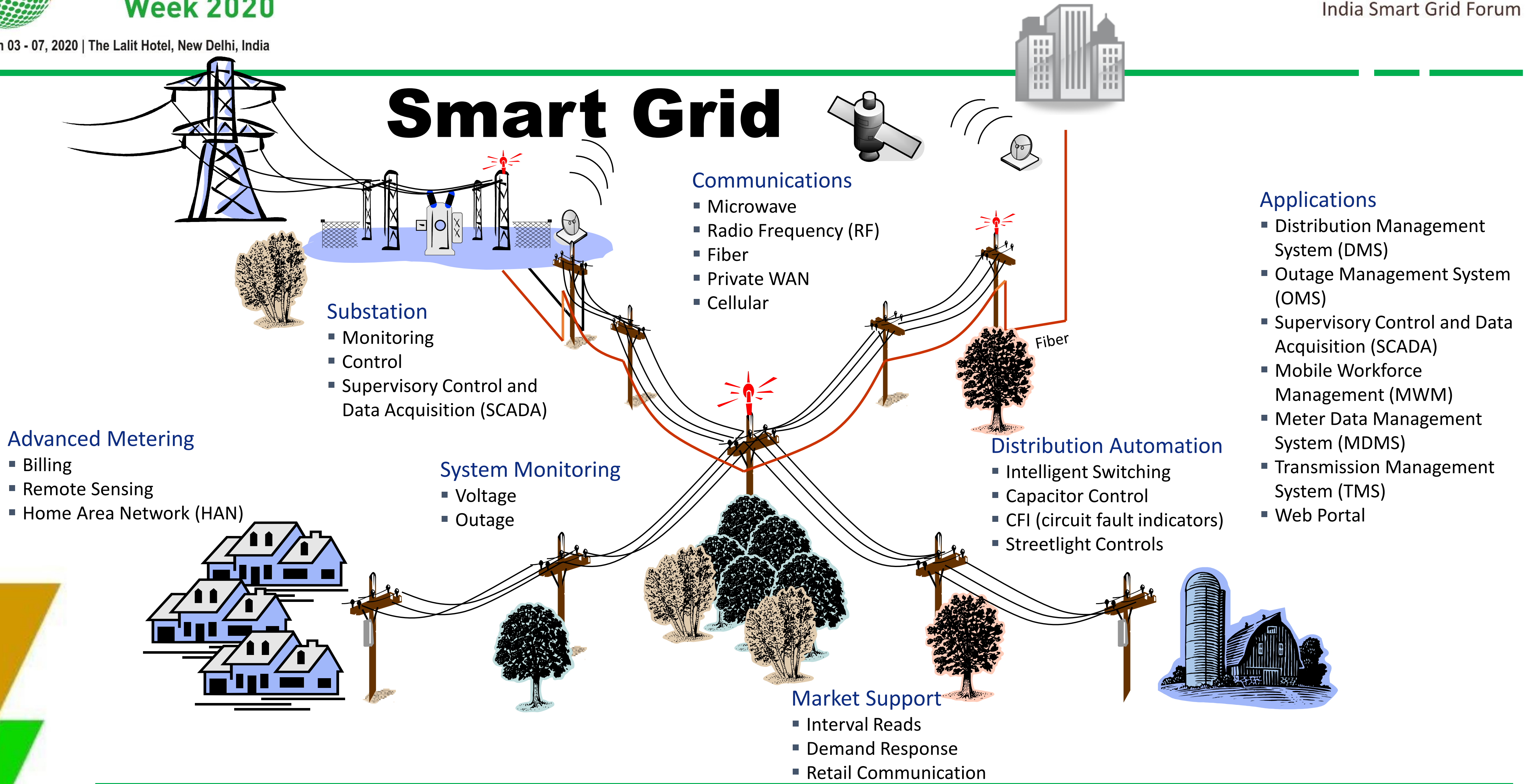
PUCT Requirements

- Provide remotely activated disconnects and reconnects on all residential meters
- Provide 15-minute interval data, which equates to almost 3,000 reads per month per meter versus the historical one read per month
- Provide consumption data to HAN and communicate with HAN devices, such as in-home energy monitors
- Give REPs ability to directly interact with the consumer’s meter, including getting on-demand reads and sending messages and control signals
- Provide market-defined Web portal functionality

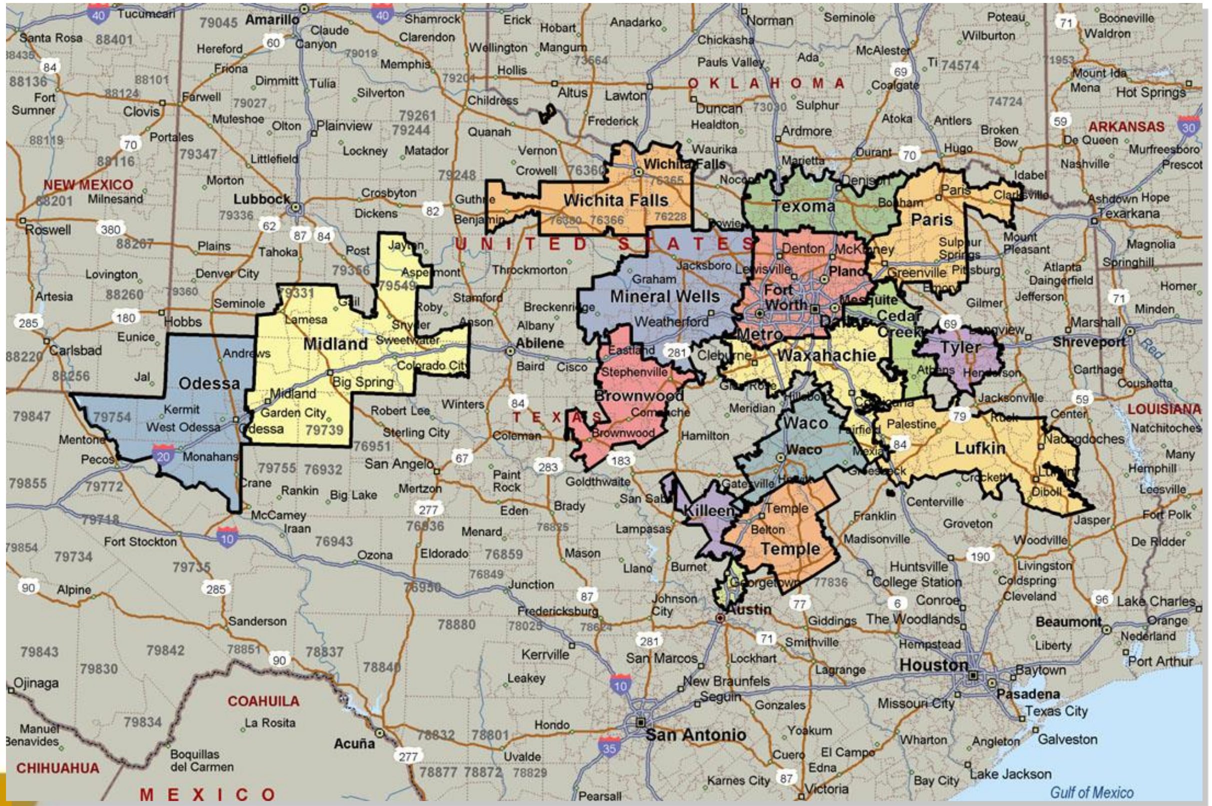
Other Market Changes

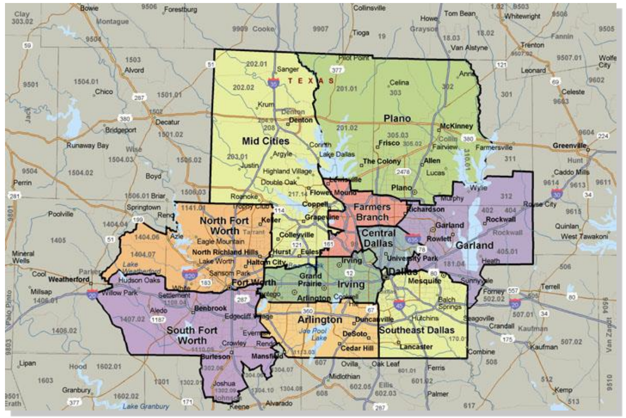
- Discretionary charges for service orders decreased based upon advanced metering efficiencies
- Texas market changed from a 5-day workweek to a 6-day workweek
- Time limits required for disconnect and reconnect of customers (prepaid accounts)
- Tampering rule gave guidelines on required evidence needed for tampering related discretionary charges

Smart Grid


Communications
Microwave
Radio Frequency (RF)
Fiber
Private WAN
Cellular
Applications
Distribution Management System (DMS)
Outage Management System (OMS)
Supervisory Control and Data Acquisition (SCADA)
Mobile Workforce Management (MWM)
Meter Data Management System (MDMS)
Transmission Management System (TMS)
Web Portal
Substation
Monitoring
Control
Supervisory Control and Data Acquisition (SCADA)
Fiber
Advanced Metering
Billing
Remote Sensing
Home Area Network (HAN)
System Monitoring
Voltage
Outage
Distribution Automation
Intelligent Switching
Capacitor Control
CFI (circuit fault indicators)
Streetlight Controls
Market Support
Interval Reads
Demand Response
Retail Communication

AMS Profile





- AMS Deployment 2008 – 2012
- Completed deployment in December 2012 with over 3.2 million AMS meters
- Currently over 3.6 million meters
- Deployment plan in Oncor’s regulatory filing

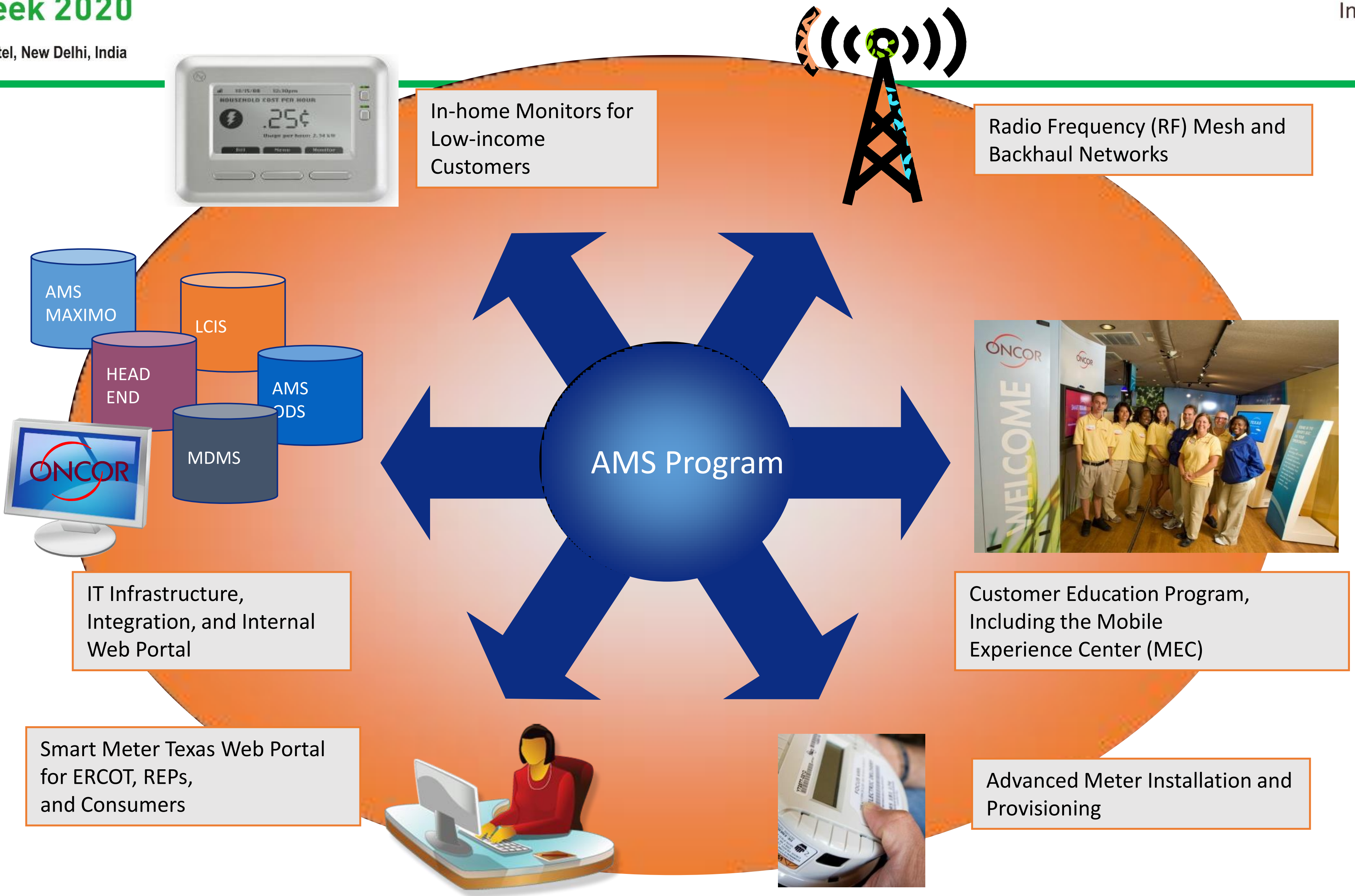
Milestones During Deployment

- Provide 15 minute non-VEE data and daily register data via FTP (December 2008)
- Provide ESIID listing of AMS meters and whether meter is RF or PLC (January 2009)
- Support HAN functionality between one device and the meter (March 2009)
- Support TOU functionality for existing rates (May 2009)
- Support prepaid electric service (June 2009)
- Support 15 minute VEE data to ERCOT and REPs (July 2009)
- Support common AMS web portal functionality (January 2010)
- Integration of AMS-OMS (March 2010)
- Meter deployment complete (December 2012)

Program Management

- Weekly Sponsor Update
  - VP and director level
  - Sponsor, Communications, Regulatory, Program Management
- Weekly Steering Committee
  - Director and manager level, decision making body
  - Measurement, Telecom, System Integrator, Vendors, IT Operations, IT Infrastructure
- Weekly Deployment Meeting
  - Staging, meter counts, change in deployment areas
  - Measurement, Telecom, Program Management
- Weekly Work Stream Updates
  - Project Management level
- All had appropriate level reports / dashboards

AMS Program Components



Technology Platform Capabilities

- Original plan vs final plan
- Business requirements vs. current capabilities
- Talk to customers

Description	Power Line Carrier (PLC) *DCSI*	Radio Frequency	Broadband over Power Line (BPL) *Current*
Communications path	Power Line	Radio (mesh or point to point)	Power Line
Bandwidth	Low	Medium	High
Geographical Application	Rural	Urban	Urban
Module Communication	Proprietary	Proprietary	Proprietary / IP
Collectors	Substation	20,000 meters	N/A
Outage Notification	Query	Last Gasp	Query
Control of other devices (potential)	Yes, except switches	Yes	Yes
TOU and Load Profile	Yes	Yes	Yes
Data Storage (Meter/Module)	Days	Days	Days

Out of date – from 2007

Meter Options - Then

One channel – kWh, analog

One read per month, manual

Meter Options - Now

<u>Meter Capabilities</u>
- Solid State
- 15 minute interval data
    - 96 readings per day
- Two way communication
- On demand reads
- Remote disconnect capability
- HAN enabled
- “Energy management device”
- Sensor

<u>Settings</u>
- Programs
    - Multiple channels available
- Configurations
    - Ability to modify meter attributes
- Software
    - Operating system
    - Metrology firmware
    - RF Mesh firmware
    - ZigBee firmware

<u>Radio Capabilities</u>
- RF Mesh
    - 900 MHz
    - Multiple frequency hopping
    - Variable power settings
- ZigBee
    - 2.4 GHz
    - IEEE 802.15

<u>Events</u>
- About 800 events
    - Outages
    - Restorations
    - Power Quality
    - Tampering / Fraud
- Configurable
    - Log only
    - Advisory
    - Alarm

Meter Options - Now

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- RF Mesh
  - 900 MHz
  - Multiple frequency hopping
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- ZigBee
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Meter Options - Now

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Meter Options - Now

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- Programs
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    - RF Mesh firmware
    - ZigBee firmware

Meter Options - Now

Events

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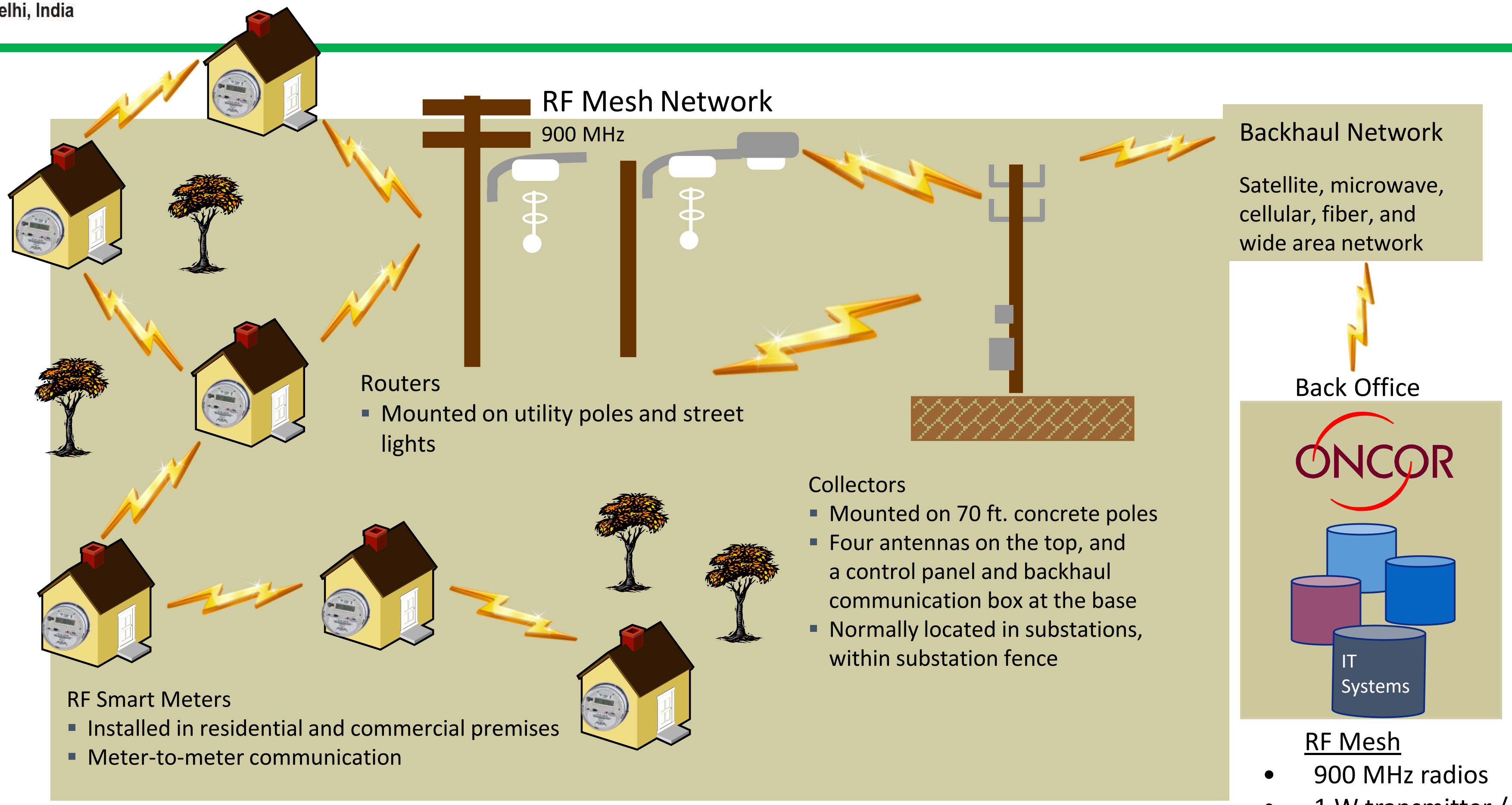
RF Mesh and Backhaul

Router



Collector

<u>RF Mesh</u>

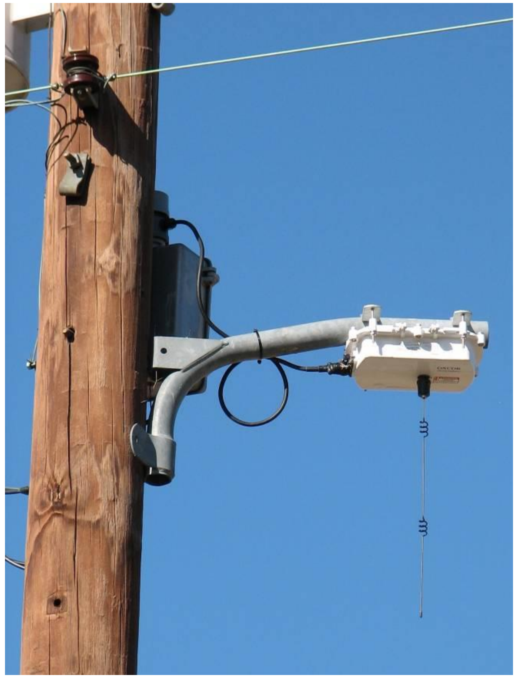
- 900 MHz radios
- 1 W transmitter / receiver
- Self-healing network
- Auto registering devices
- Network can be shared with distribution automation devices

RF Repeater/Router

- Receives meter data from the smart meter via the RF Mesh network and forwards meter data to the appropriate collector:
  - Installed and identified by GPS coordinates
  - Radio antenna points down
  - Serial number and Oncor logo visible from below
  - Considered "low power" and not a hazard to work near
  - Equipped with internal battery backup—can operate up to 8 hours without power

RF Repeater/Router Locations

- Normally mounted on street lights and utility poles
- "Extended height" routers for rural areas with low meter density
- Alternate design for pedestal mounts for neighborhoods with underground secondary



Mounted on utility pole

Mounted on street light

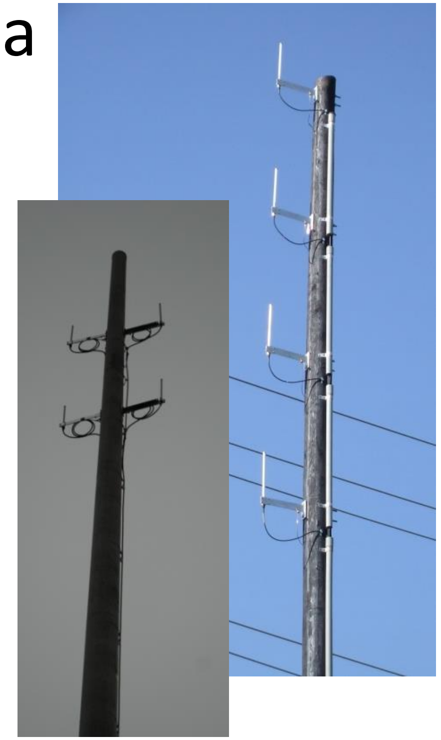
RF Collector

Receives meter signals from the repeaters/routers via the RF Mesh and transmits them to the Command Center via the Backhaul network:

- Contain head end radios and backhaul communications for the AMS network
- Mounted on 70 ft. concrete poles
- Four RF Mesh antennas on top
- Locked control panel and backhaul communication box at the base

Inside of Control Panel

Base of Collector Pole



Top of Collector Pole

RF Collector Locations

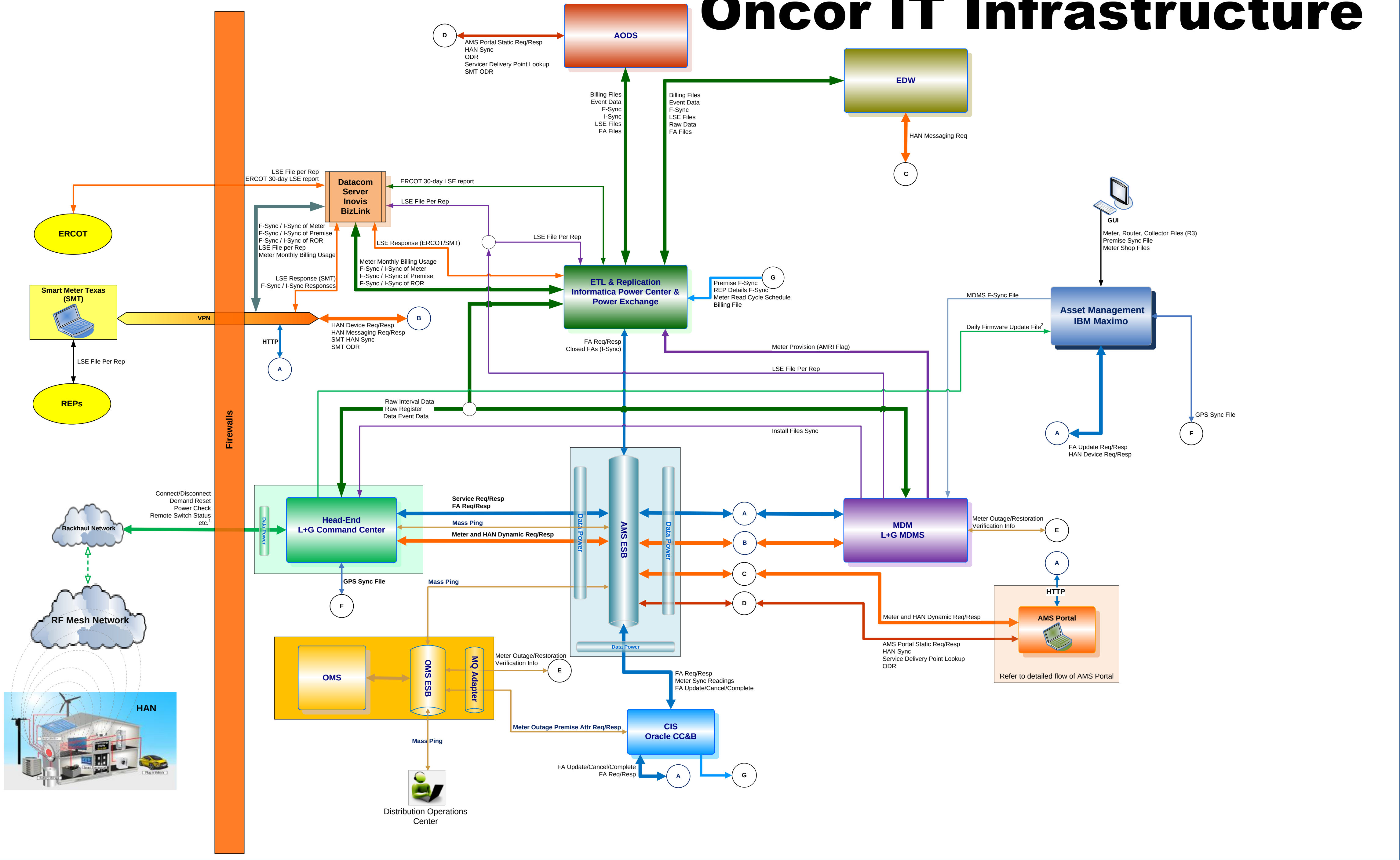
- Normally located at substations, within the substation fence
- Exceptions for areas with low meter density or limited bandwidth

Collector Takeout Point at Substation

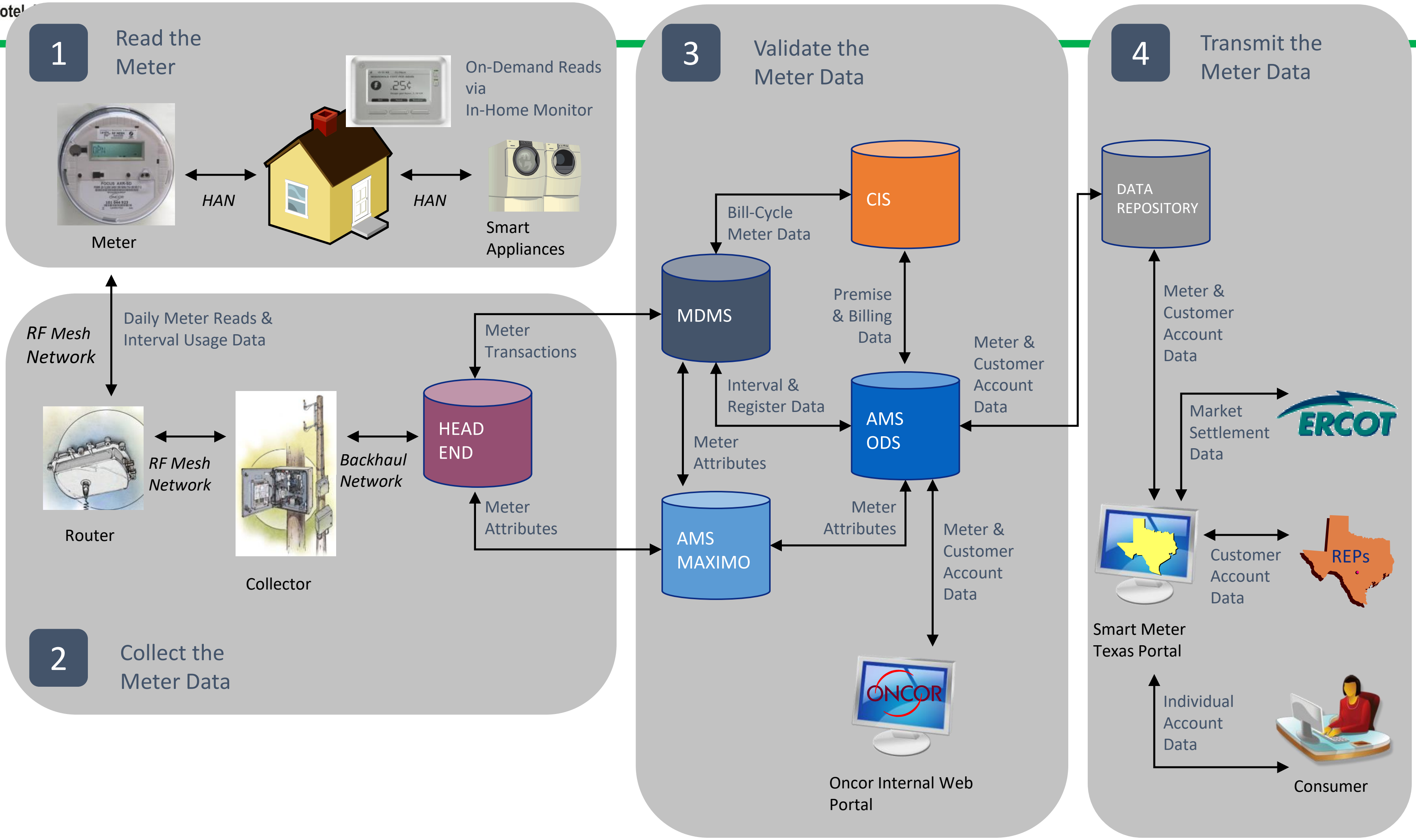
View of Collector Within the Substation Fence

View of Collector Located Outside of Substation

Oncor IT Infrastructure



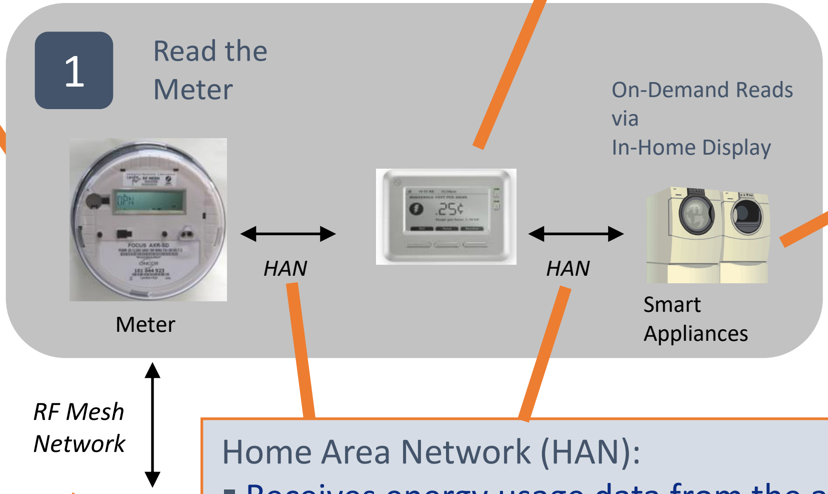
Meter Data Flow



Meter Data Flow – Read the Meter

Advanced Meter:
- Records energy usage at 15-minute intervals
- Transmits meter data to the premise HAN device via ZigBee Smart Energy 1.0
- Transmits meter data to Oncor via the RF Mesh network

In-home Monitor
- Receives meter data from the HAN
- Displays energy usage to the consumer in near real-time
- Communicates with the HAN to manage smart appliances



Smart Appliances
- Connect to the HAN via ZigBee Smart Energy 1.0
- Projects underway to bring smart appliances to market

Home Area Network (HAN):
- Receives energy usage data from the advanced meter
- Sends meter data to the HAN device
- Communicates with smart appliances

RF Mesh Network:
- Receives meter data
- Sends meter data to the router

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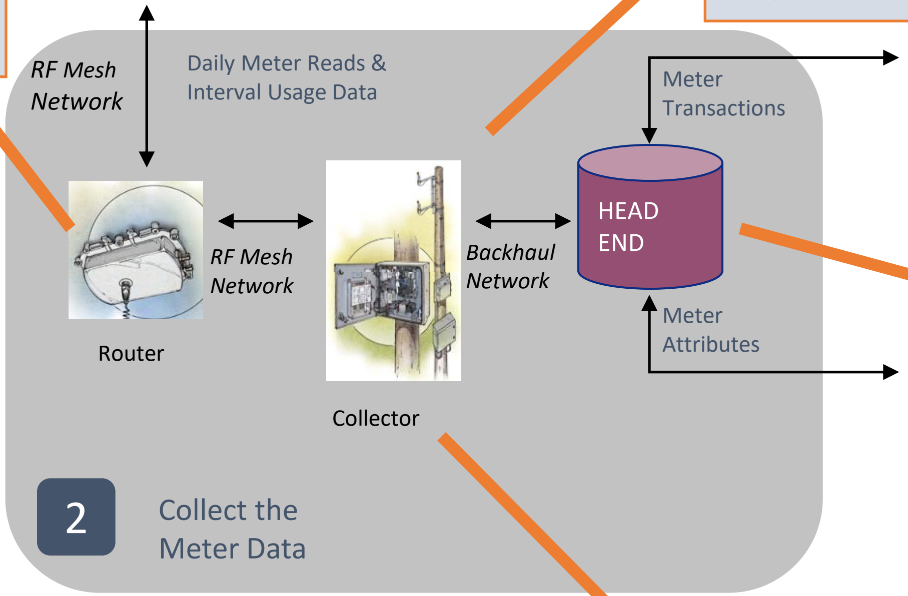
Meter Data Flow – Collect the Meter Data

India Smart Grid Forum

Router:
- Receives meter data from the RF Mesh network
- Forwards meter data to the appropriate collector

Backhaul Network:
- Uses wide area network (WAN), fiber, microwave, or cellular components
- Forwards meter data to Head End

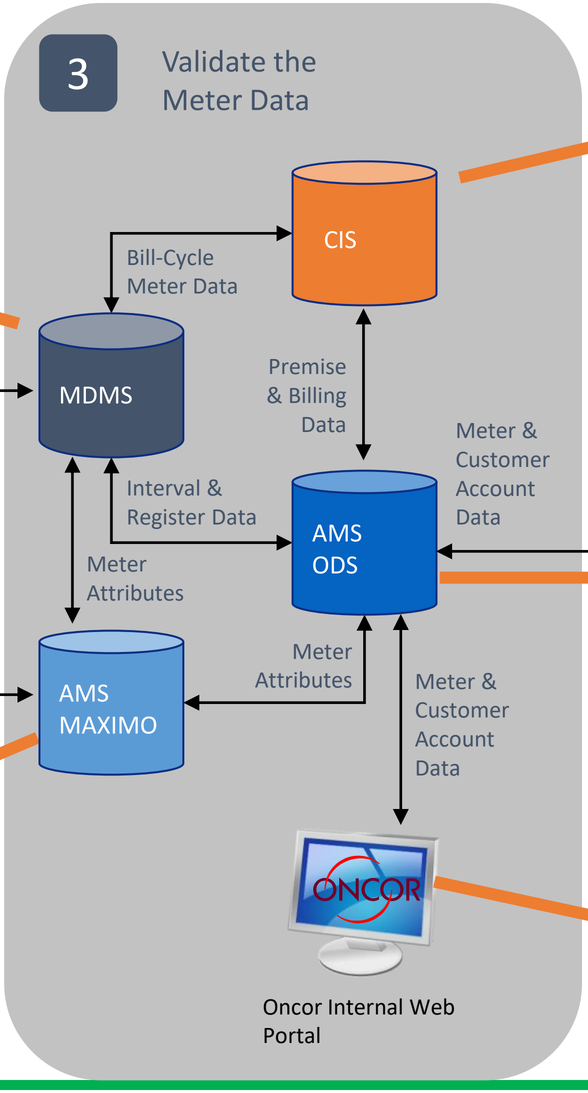


Head End:
- Collects meter data
- Receives meter attributes from AMS Maximo
- Forwards meter data to the Meter Data Management System (MDMS)

Collector:
- Receives meter data from the router via the RF Mesh network
- Forwards meter data to Head End via the Backhaul network

Meter Data Flow – Validate the Meter Data

Meter Data Management System (MDMS):
- Receives the meter data from Head End
- Receives meter attributes from AMS Maximo
- Validates the accuracy and completeness of the meter reads through the process of validation, estimating, and editing (VEE)
- Provides estimates for any missing interval data
- Creates billing-quality data
- Sends bill-cycle meter data to LCIS
- Sends interval and register data to the AMS ODS database



Customer Information System (CIS):
- Receives bill-cycle meter data from MDMS
- Receives meter attributes from AMS Maximo
- Ensures meter data complies with business rules
- Creates billing files
- Sends premise and billing data to AMS ODS

AMS Operational Data Stores (ODS):
- Receives interval and register data from MDMS
- Receives premise and billing data from LCIS
- Integrates interval data and billing data to make analysis and reporting easier
- Sends meter and customer account data to the internal Web portal and the data repository

AMS Maximo:
- Maintains asset information and associated equipment
- Sends meter attributes to MDMS and AMS ODS

Oncor Internal Web Portal:
- Receives the meter data from AMS ODS
- Provides data for internal reporting and analysis

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Meter Data Flow – Transmit the Meter Data

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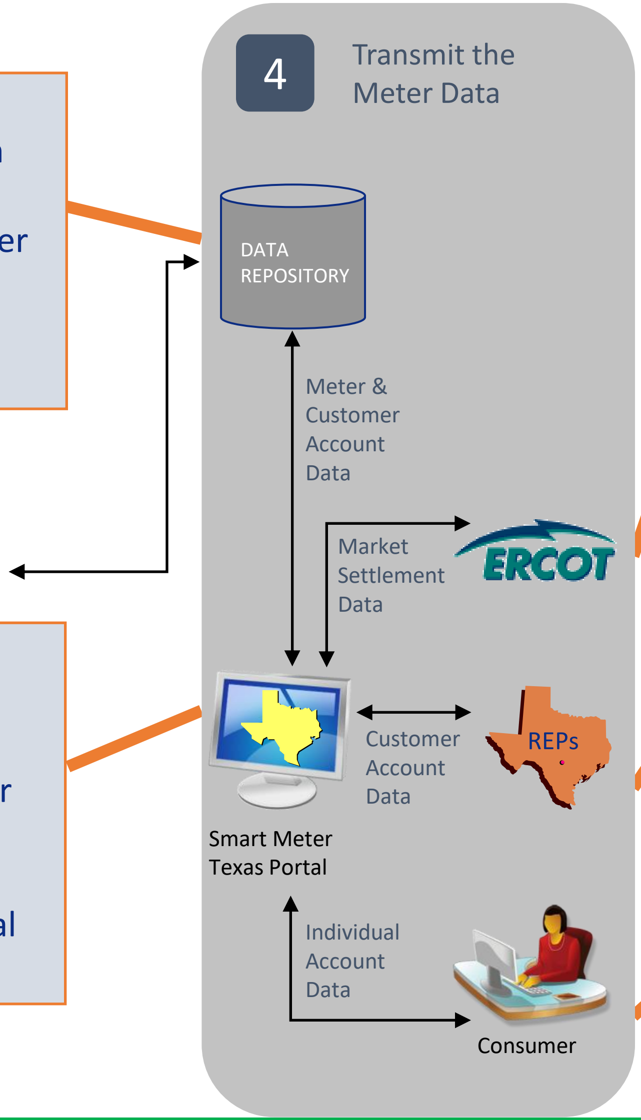
Data Repository:
- Receives the meter data from AMS ODS
- Organizes and stores the meter data by REP
- Sends account data to the Smart Meter Texas Portal



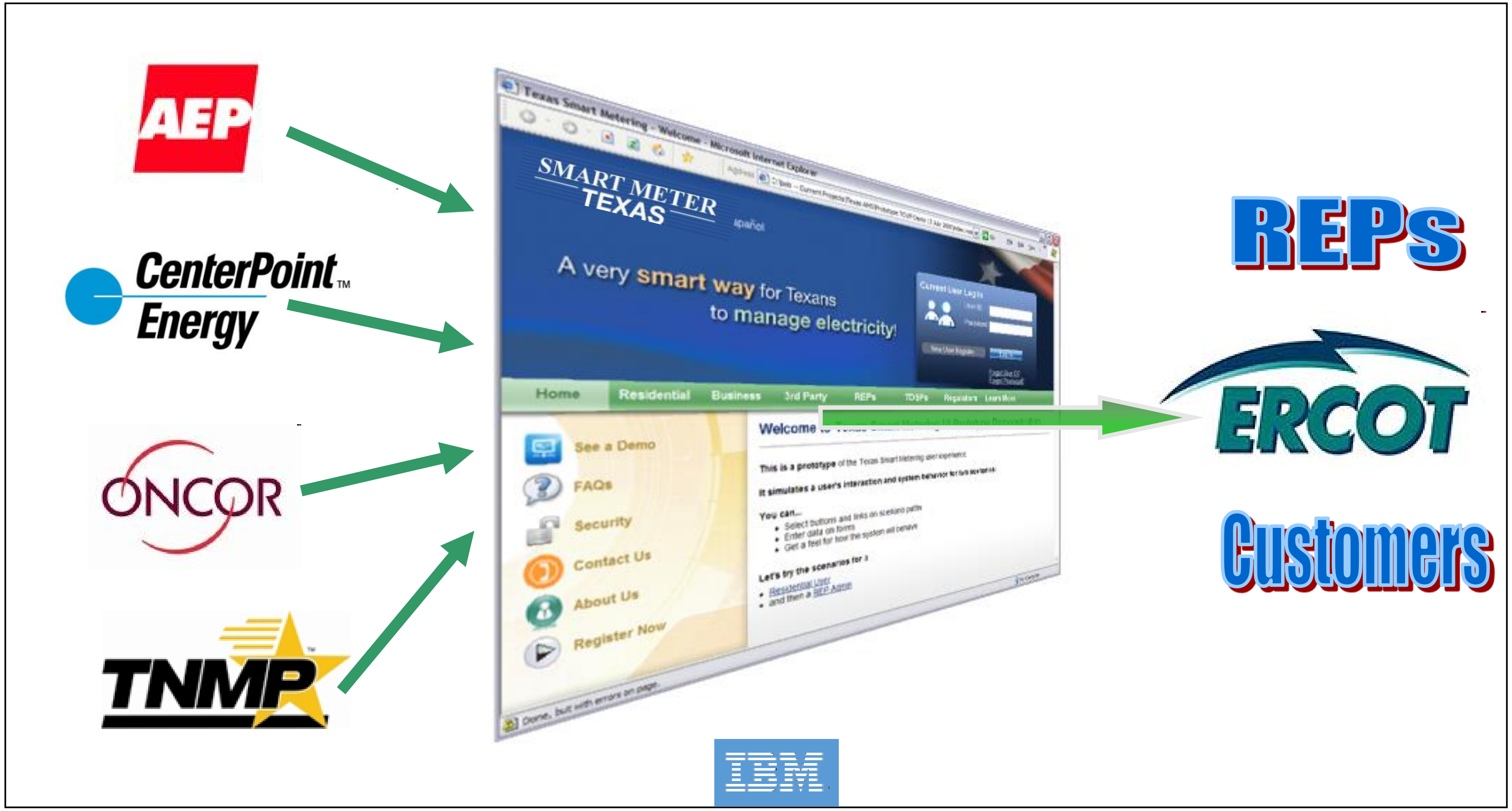
Smart Meter Texas Portal:
- Provides self-service market settlement data to ERCOT
- Provides self-service customer account data to REPs and authorized third parties
- Provides self-service individual account data to consumers

ERCOT: Uses the market settlement data to assess administrative fees, publish billing statements, and resolve disputes

REPs: Use the customer account data to bill customers, manage customer accounts, and support innovative new programs and pricing options

Consumers: Use their account data to make more informed choices about energy use

Smart Meter Texas Portal



Smart Meter Texas Portal

Historic 15 minute interval usage data

HAN device provisioning

On demand read

Customers

Wires Company's

REPs

Separate GUIs

API

Historic 15 minute interval usage data

HAN device provisioning

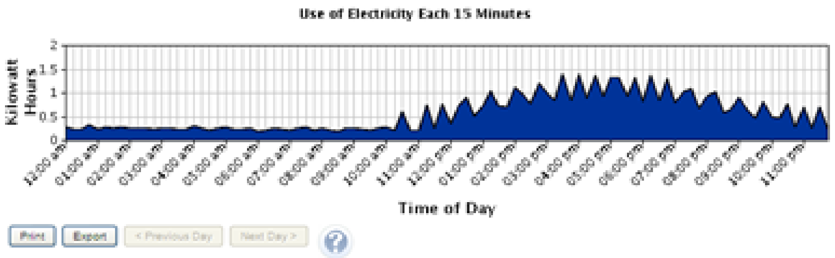
HAN messaging

On demand read

Smart Meter Texas Portal

- Customer visibility of data
- Data available:
  - 15 min. interval data
  - Daily register reads
  - Billed consumption
- Ability to make an On Demand Read
- Ability to download data
- Ability to provision or deprovision HAN devices

Daily Usage (each 15 minutes) - Kilowatt Hours for 06/02/2012



Start Time	End Time	Usage(kWh)	Act./Est.
12:00 am	12:15 am	0.292	A
12:15 am	12:30 am	0.238	A
12:30 am	12:45 am	0.248	A
12:45 am	01:00 am	0.338	A
01:00 am	01:15 am	0.248	A
01:15 am	01:30 am	0.295	A
01:30 am	01:45 am	0.277	A
01:45 am	02:00 am	0.299	A
02:00 am	02:15 am	0.259	A
02:15 am	02:30 am	0.263	A

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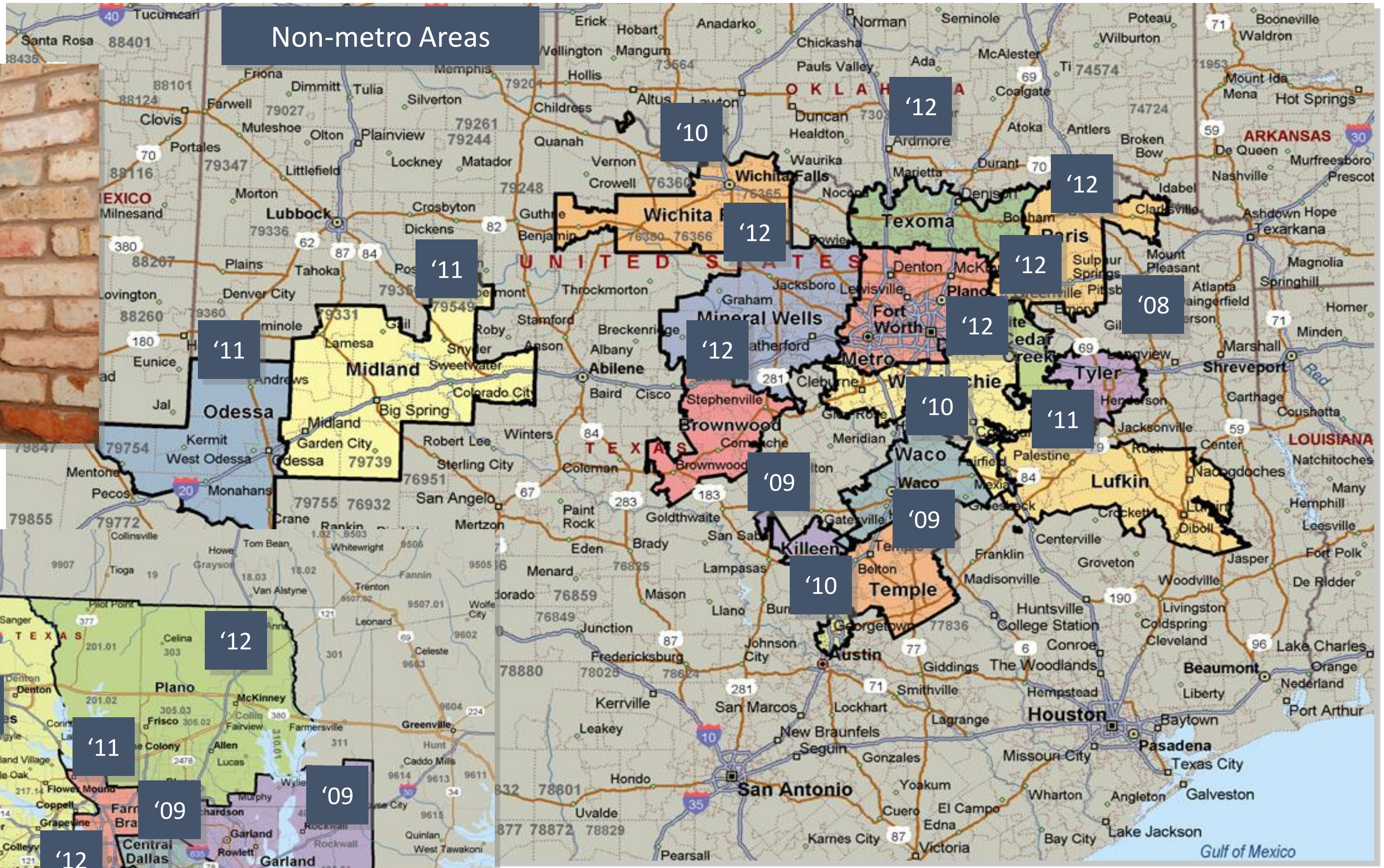
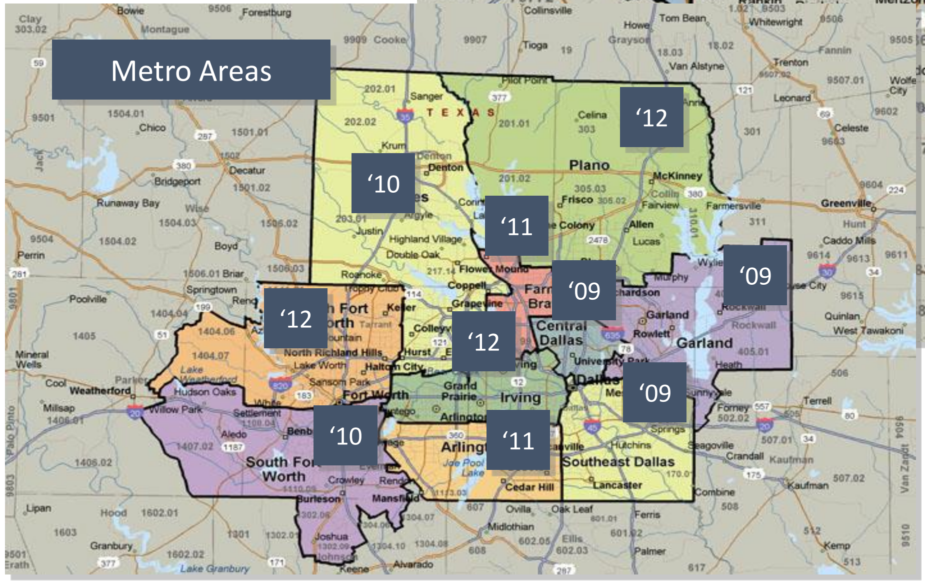
Deployment Rollout

ISGF India Smart Grid Forum





Meter Validation Cycle

1. 100% of meters are tested at the factory
2. Sample pallets are tested at Oncor
3. Meters electronically issued to each installer
4. On-line validation of service order completion in field
5. Latitude and Longitude recorded
6. End of day meter inventory verification
7. Old meter status validation within 36 hours
8. Second recording of old meter out reading
9. Old meter picture with out read
10. Back office comparison of field out read vs second read
11. Routes enabled for billing when saturated (RF network)
12. At least one manual billing read and meter verification

Customer Education Program

Customer and Stakeholder Education Program

SMART TEXAS℠ rethinking energy

Focus was on benefits to the individual:	Target audiences included:	Campaign emphasized interactive touch/feel
▪ Putting control in the hands of consumer ▪ Ability to have positive impact on environment	▪ End use customers ▪ Retail electric providers ▪ Local and state officials ▪ Community-based outreach groups	▪ Solid outreach program aimed to promote understanding of AMS ▪ Host local site events across Oncor system to educate general public

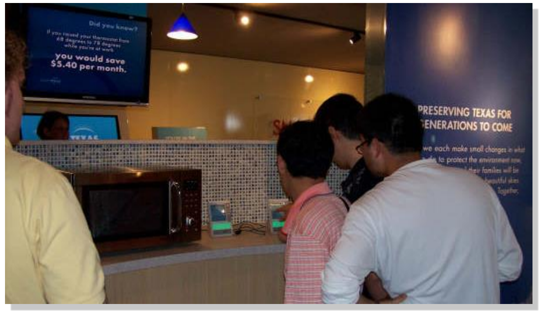
Mobile Experience Center

- Mobile Experience Center (MEC) – part of Oncor's customer education
- MEC visited communities corresponding to AMS rollout (pre & post)
- Regulatory and Legislative visits
- Other venues included:
  - Selected sponsorships
  - State Fair of Texas, East Texas State Fair, Dallas Home & Garden Show

Oncor's Smart Texas℠ Mobile Experience Center

- Bringing an educational exhibit to the communities we serve
- 53-ft. double expansion trailer with
  1,000 interior square feet
- Holds between 50-60 people
- Outdoor JumboTron with 12'x9' screen to attract visitors
- Face to face opportunities

Interactive, Interesting and Inviting



Zones that build on each other for a complete consumer experience using interactive videos, trivia and real-world demonstrations

- Outside – Learn differences between old and new meters
- Zone 1 – Learn about Oncor and its use of technology to improve electric delivery
- Zone 2 – Understand your energy consumption
- Zone 3 – Experience how different household appliances affect your energy usage
- Zone 4 – Imagine the future of a Smart Texas
- Zone 5 – Observe how rethinking energy will help the environment
- Registration and giveaways
- Content was regularly updated throughout deployment

Customer Education

Leveraging Social Media

twitter

- Advertise events
- Post the latest news
- Request fact checks from reporters/post corrections to news stories
- Provide immediate updates to consumers (i.e. power outages)

facebook

- Demonstrate your brand personality
- Post photos, videos, event calendars
- Address complaints, customer service issues
- Engage your audience – ask questions, tell stories

Plans Included Ways to Enable Consumers to Make an Impact Soon

- Surcharge included funding in-home monitors to low income or hard to reach consumers
  - Studies have shown that merely providing consumers with real time feedback can have up to a 5% impact on consumption

- For those that attended the local MEC events, Oncor gave Compact Fluorescent Lamps
  - Monthly savings from replacing one 100 W incandescent bulb with a CFL will fund the surcharge

Home Area Network (HAN)

- Multiple products have been tested with Landis & Gyr / Oncor Test Lab
- Text messaging
- Load control / demand response
- Pricing signals
- Functions available now
- Device availability limited

But note that Zigbee 1.1 is obsolete. Use Zigbe 2 Application layer on other transport (DEN note 2020)

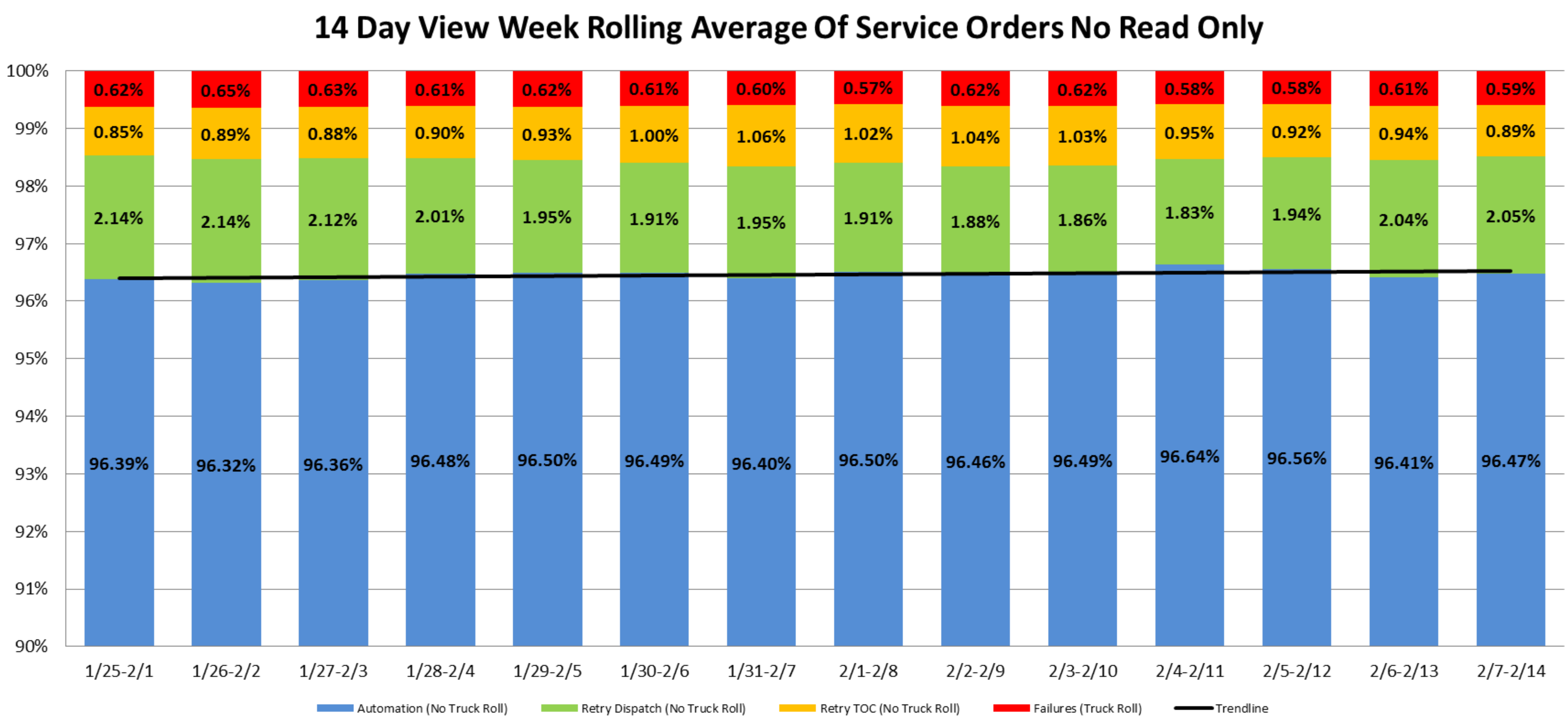
O&M Savings

Meter Readers & Field Service personnel

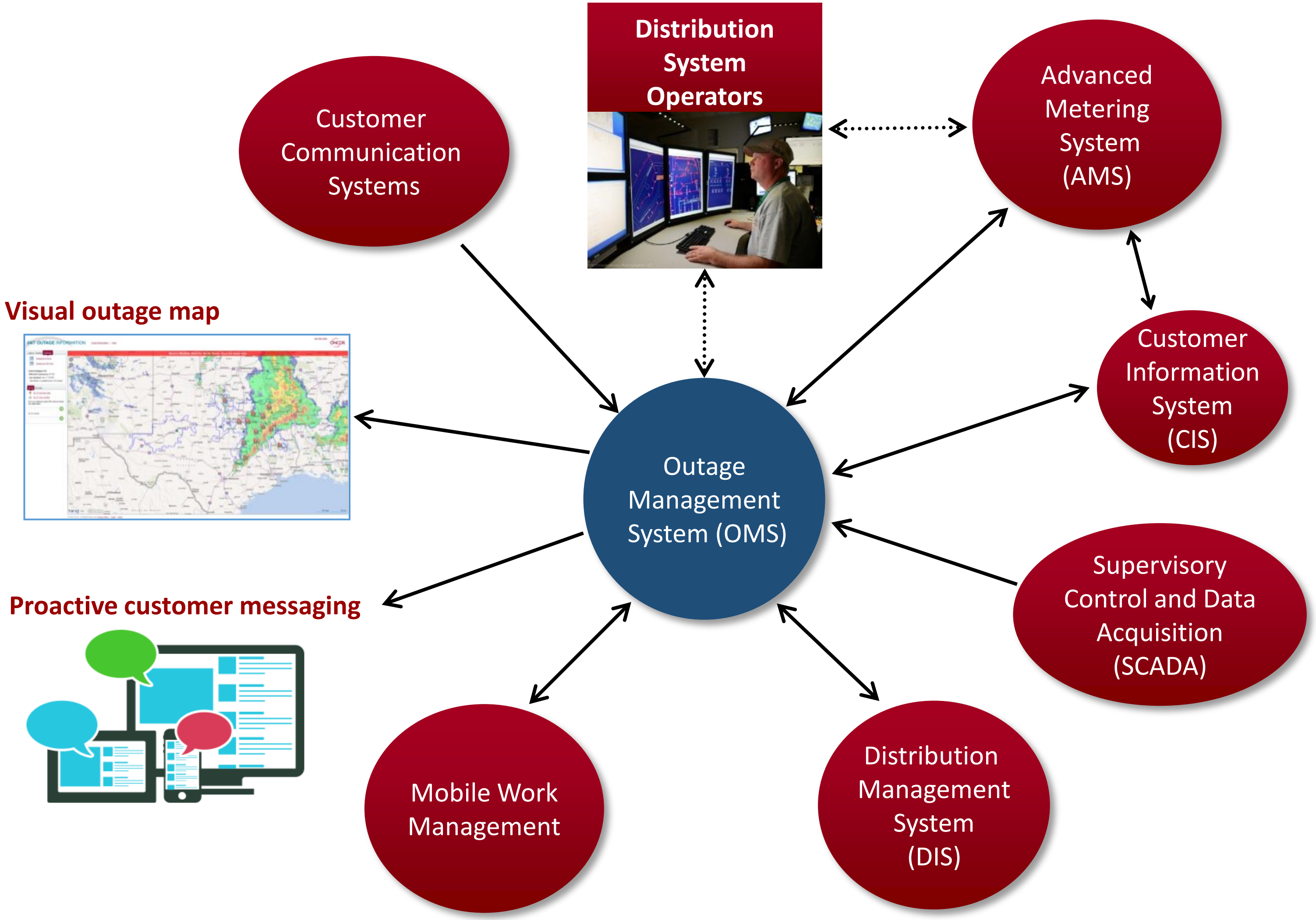
- Salaries
- Truck:
  - Leases
  - Maintenance
  - Fuel
  - Insurance
  - Environmental impacts

SAFETY!

Service Order Automation



Advanced Technology Leads To a System of Systems and Fully Automated Analytics



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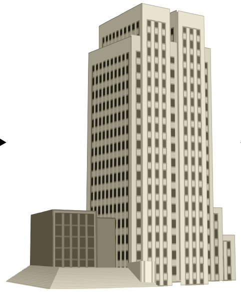
AMS and OMS Integration

LG
40 sec
↓
EOM
↓
MOF 165 sec
XFMR Logic → ↓
Transformer retry – 120 sec

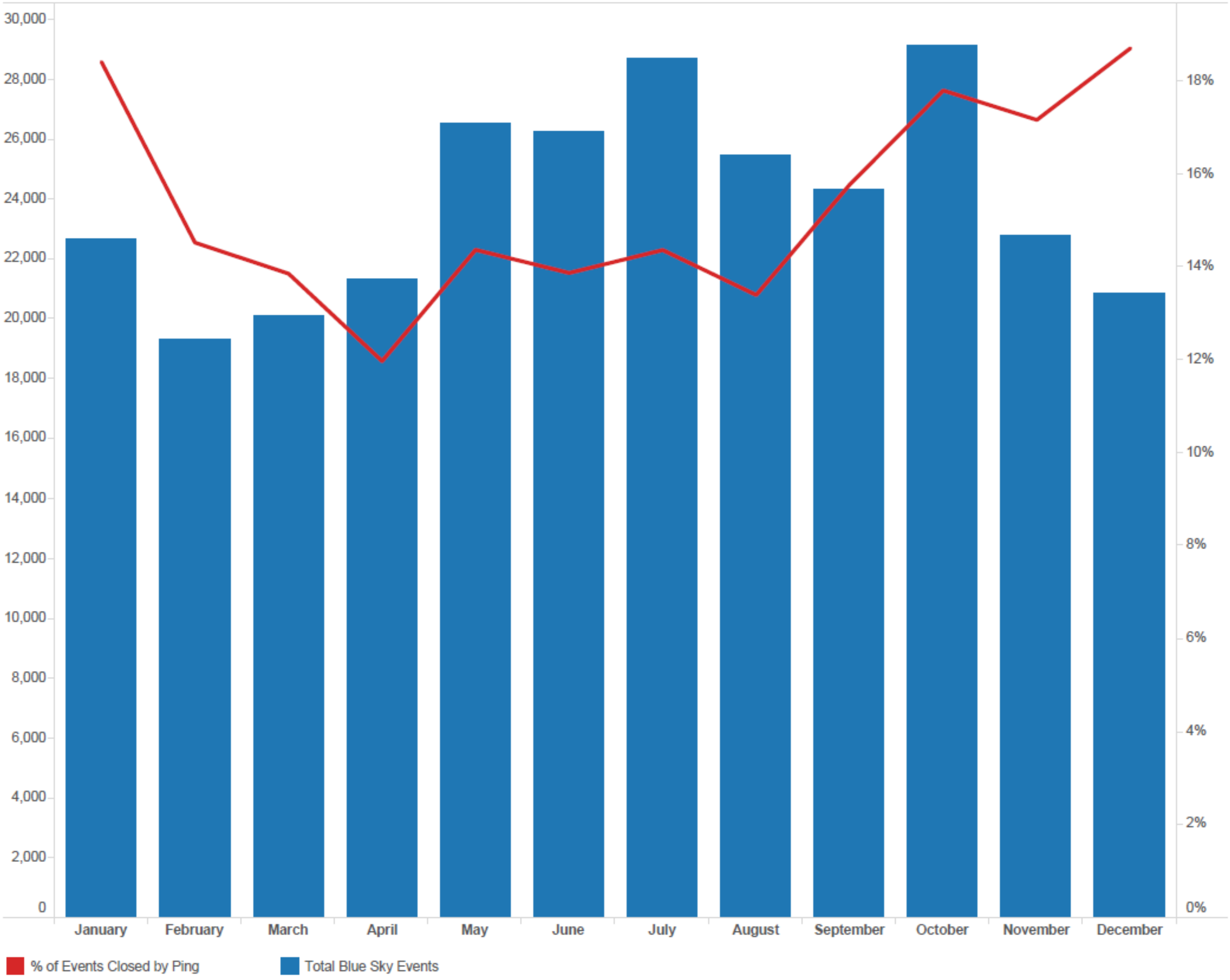
- At the onset of an outage
  - Meters send a message after a 40 second outage
  - AMS filters the message
    - Ensures at least two meters on a transformer detects the outage
    - Reduces electronic traffic to the OMS
  - AMS sends filtered outage signals to OMS (faster and more dependable than customer calls)



Once restoration is completed, the system sends us a notification

On customer initiated outage calls, operators will validate Oncor's service to the meter by on demand read

Percent of Times Truck Rolls Avoided in 2018 by Pinging Meter



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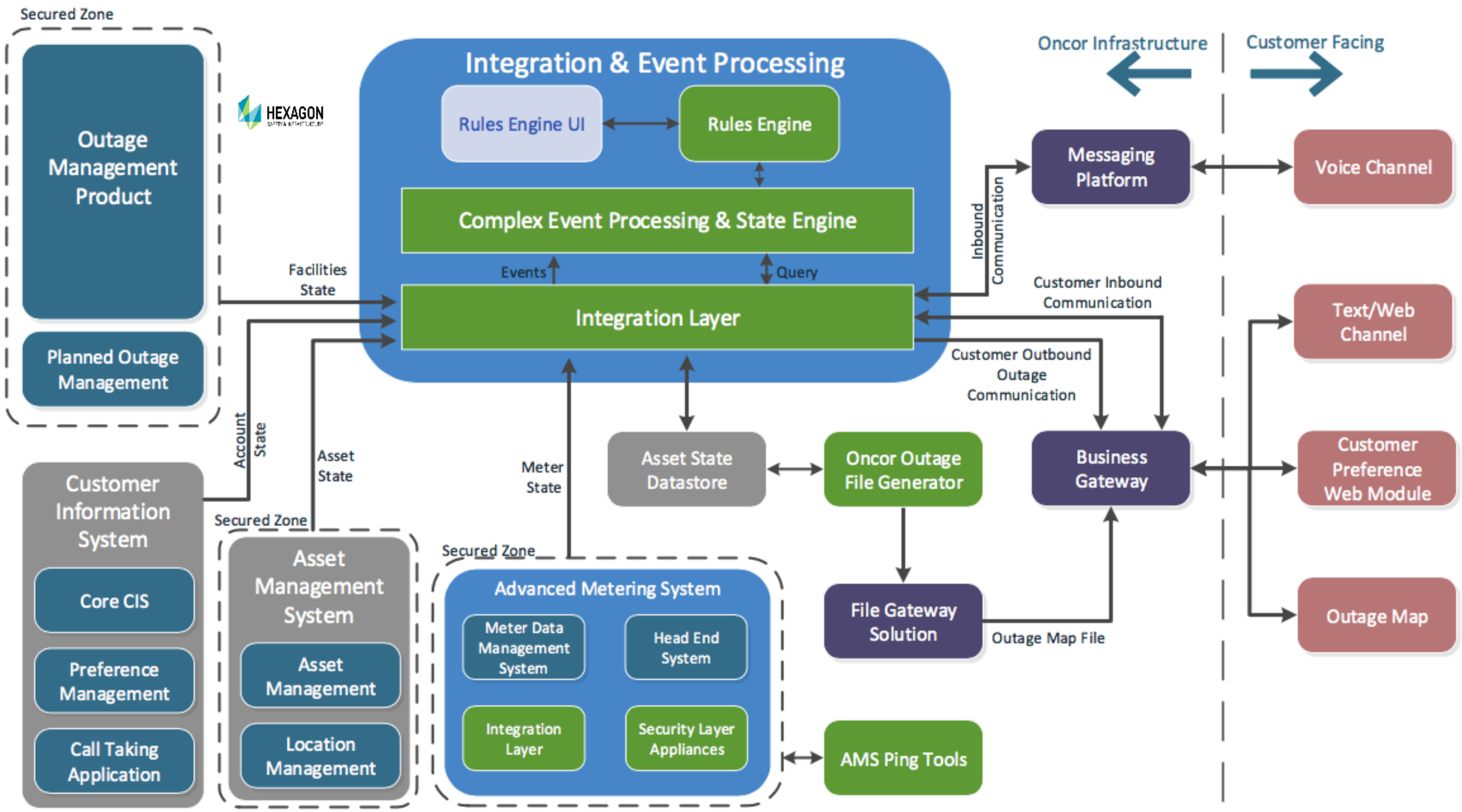
Proactive Customer Communication

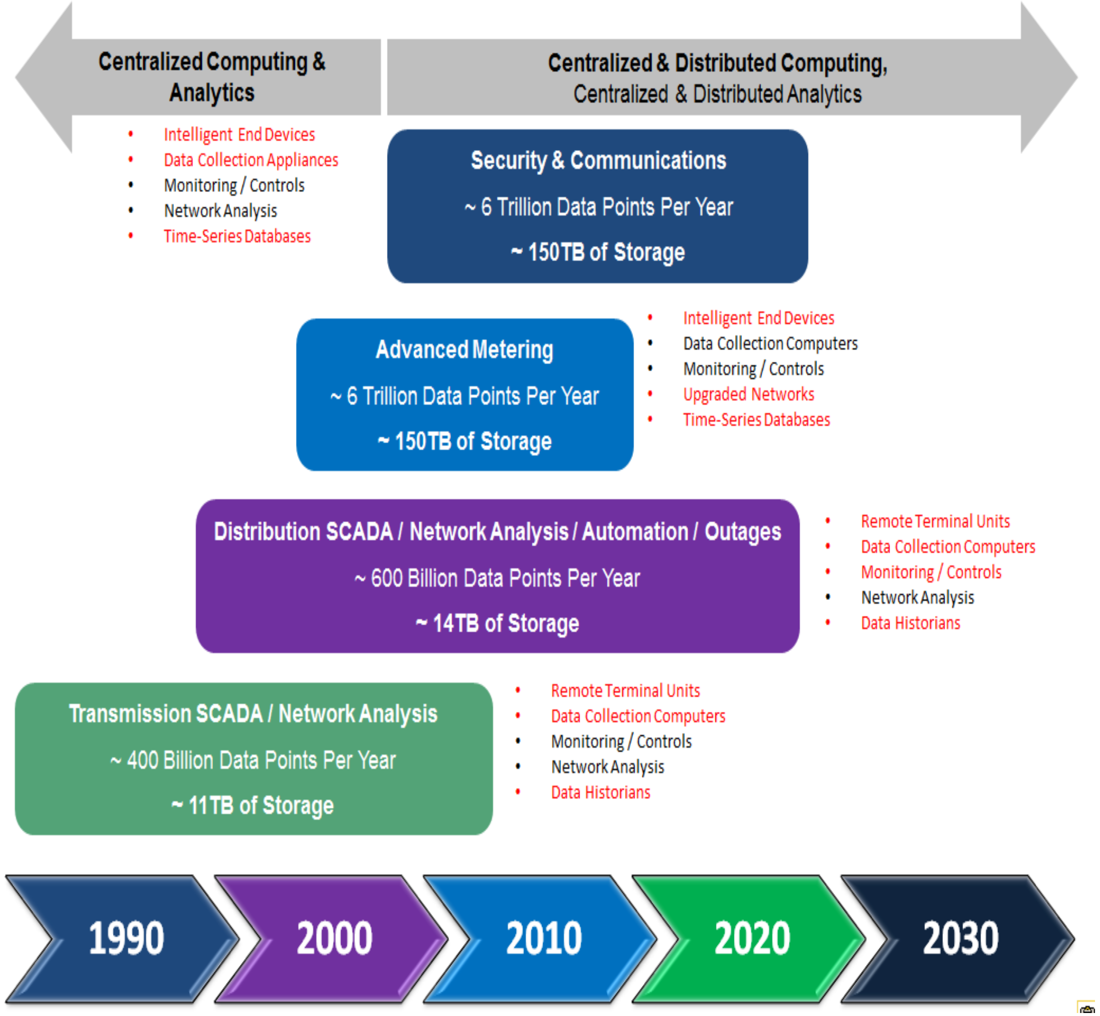


Uses AMS for confirmation for outage/restore

Incorporates advanced ETOR predictive engine

Analytics Drivers

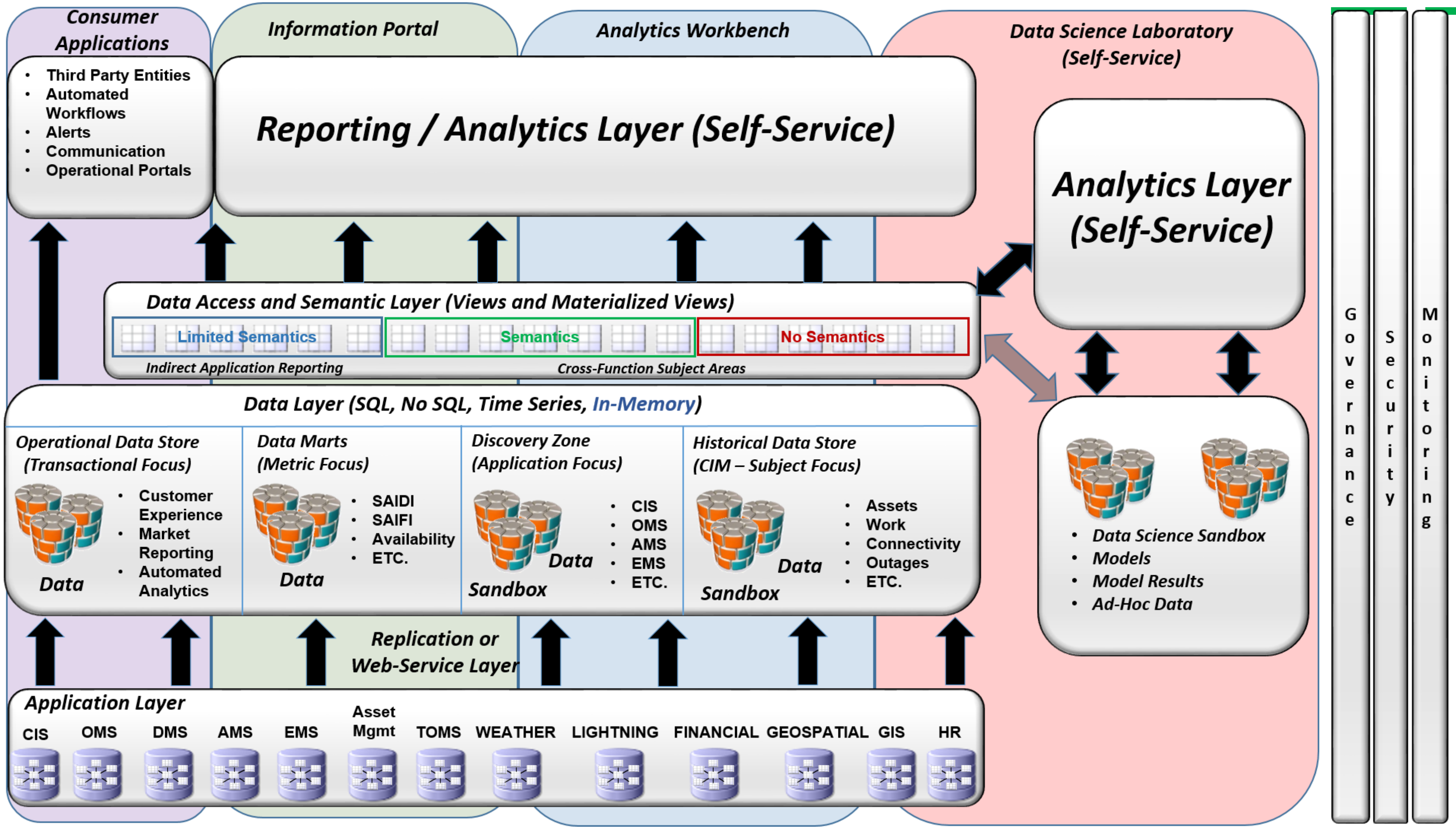
- Start with the basics
  - Big data vs big data analytics
  - Managing the data / governance
  - Data quality
  - Data correlation
  - Time synchronization
- Requirements vs tools
  - What is the business need?
  - What is the issue?
  - What are we trying to do?
  - What data has value?
- Process vs tools
  - Define the process and commit to the process
  - How do you get a prototype / POC analytics program into production (automation)
- Requirements and Process lead to tools



Why analytics?

- Data correlation from multiple sources
- Root cause analysis
- Detect and identify issues
- Prediction and projection of work processes
- Integrate new information not previously available
- Continuous process improvement
- Simplify existing work processes
- Drive automation

Oncor's Analytics Platform



Data Analysts

Small cross functional group develops and guides maintenance strategy

Super-users are a combination of traditional utility employees and newly added data scientist, management, and analyst personnel

- Focused on higher order tool set
- Timely repetitive interactive training from experts
- Immediately use the skills acquired
- Ability to “phone a friend”
- Developing a “train the trainer” approach

Significant analytical capability is distributed throughout the organization, especially with many of the newer employees

- Training on more basis tool set
- Focused on newer more computer analytical employees
- Over time, some of the higher order tools may be deployed

Power Quality






- Events received indicate a problem
- Sometimes a meter, many times an indication of a problem on the distribution network
- Common issues
  - Bad or loose connection
  - Transformer issue
- Required a change to field resources training
- Planned outage less expensive than equipment failure
- Trust the data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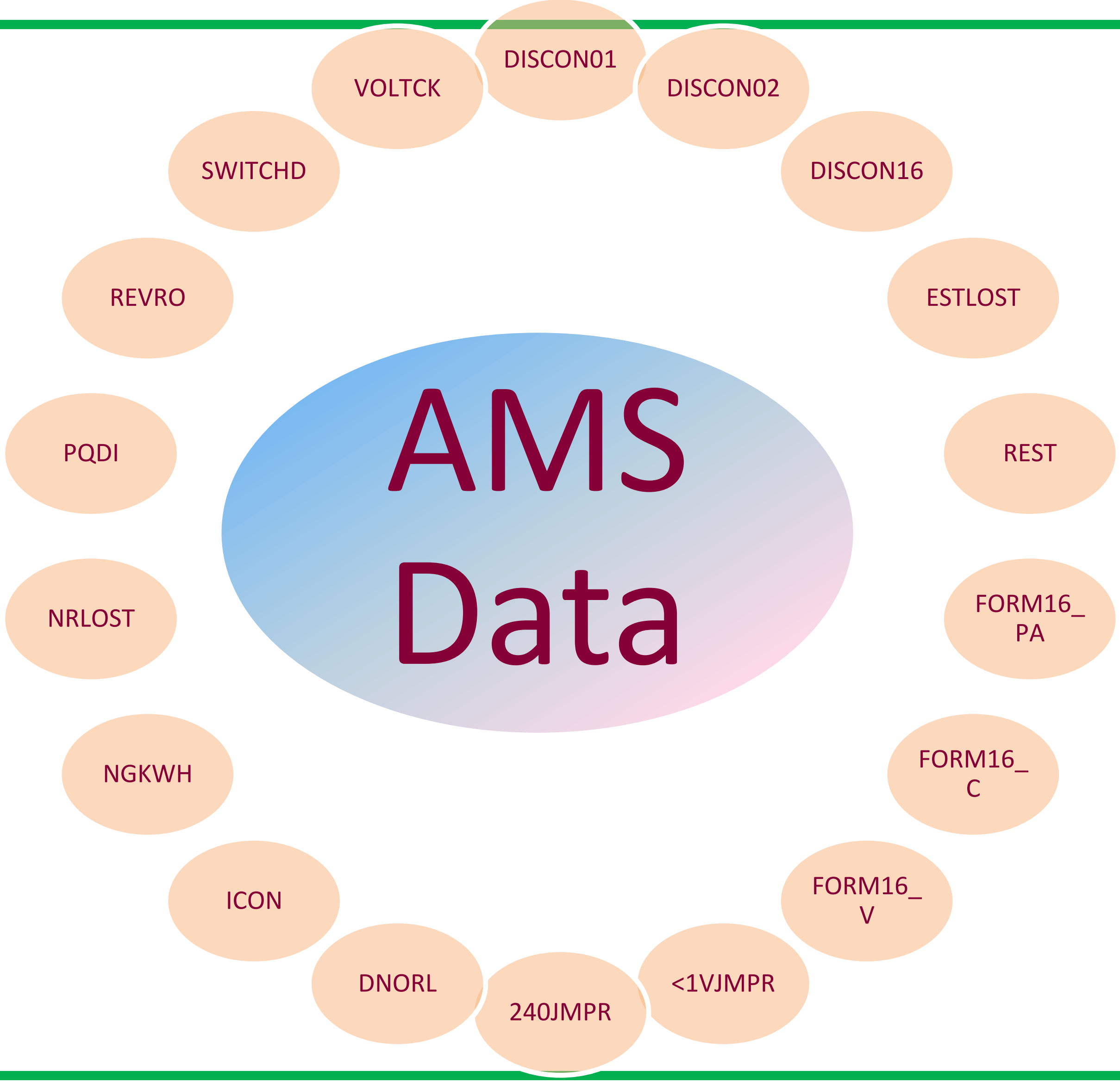
Distribution Automation Gateway

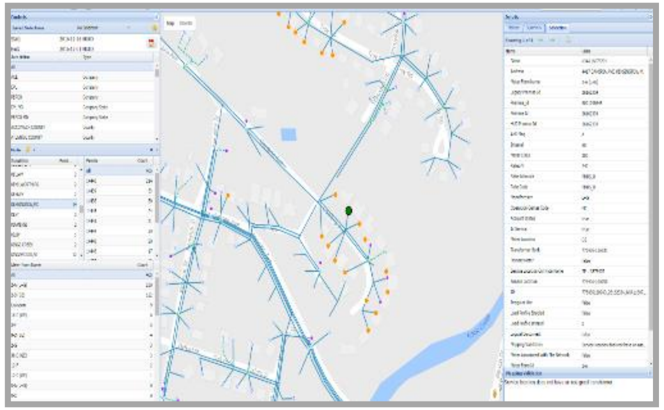
- Shared use of the RF mesh
- DA equipment has higher message priority
- DA Gateway puts a DNP3 wrapper on message
- Current use: capacitor bank controls
- Future: circuit fault indicators, streetlights

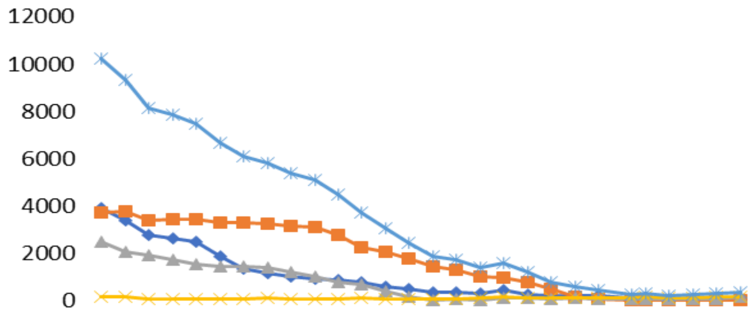
Tampering / Theft
(Revenue Protection / Non-Technical Losses)



Network Connectivity Model

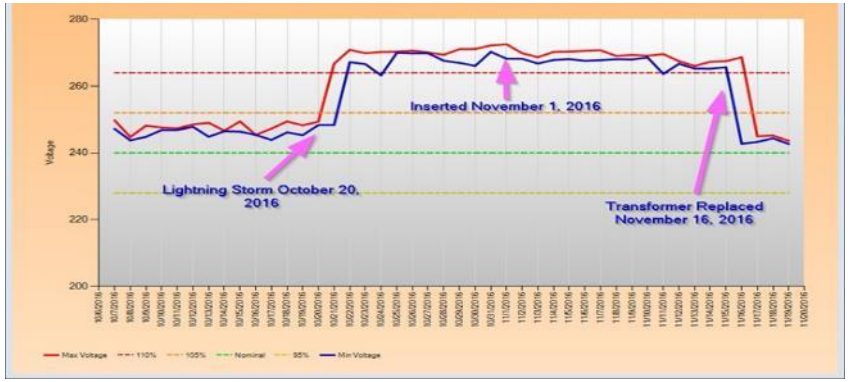
- Meter premises to distribution transformer relationship
- Utilizes 15 minute voltage and GPS
- Identifies incorrectly associated meters
- This analytics solution helps numerous other models
- Automated correction scripts
- Meter to Xfmr phase relationship
- Voltage algorithms
- Distance algorithms





Asset Health

- Monitoring meters per distribution transformer
- Benefits:
  - Reduced outage time
  - Reduced overtime costs
  - Maintenance during normal business hours
  - Replaced before the customer was affected – no customer call



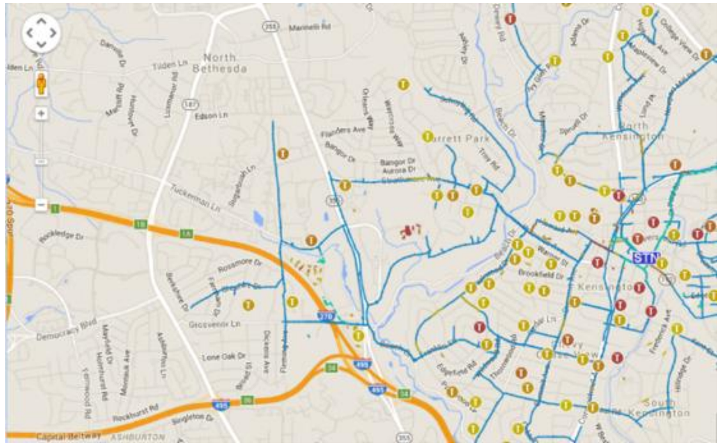
Resolved Issues (Mar 2016 –Dec 2017)		
Meter	Voltage Regulation	Transformer
32 Meters	506 Feeders	821 XFMRs

Avoided over 2.5k customer interruptions and 680k customer interruption minutes

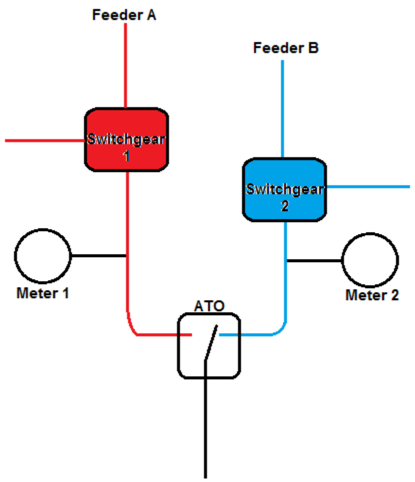
Transformer Load Forecasting

- Predicts transformer loading using AMS data, day of week, and weather data.
- In service now & integrated with Distribution Operators' tool set
- Feeder load forecast based on temperature, type of day and hours for 3000+ feeders
- Updated daily

The ultimate goal is incorporating a day-of-week and temperature estimation for all distribution transformer or primary meter points into the OMS and planning systems



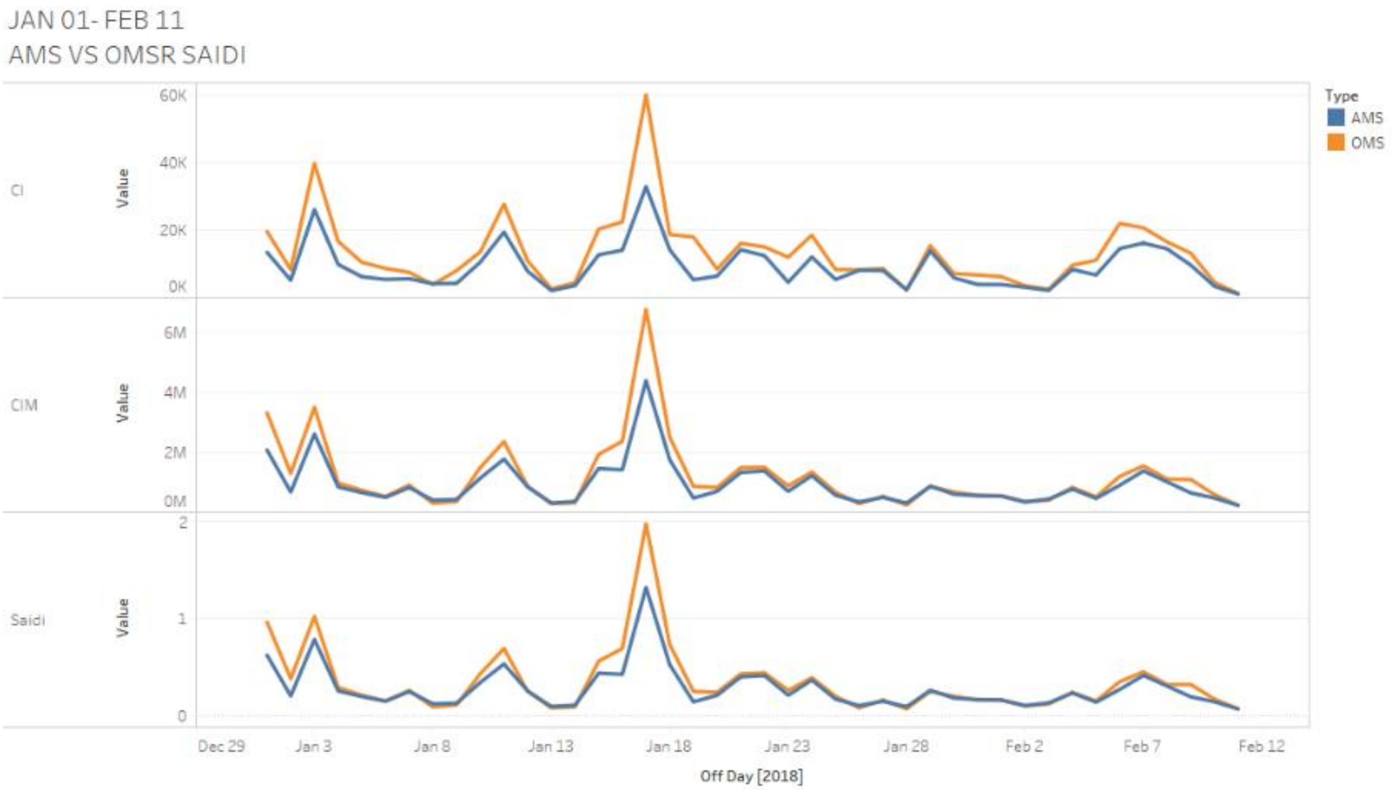
AMS as SCADA



- Interactive One-Line Schematic:
  - Fault Indication
  - As-operated system configuration
  - AMS Meter data pushed every 5 minutes
    - Meter, three phase voltages and currents, Timestamp of last push, and customer
- Ability to request the above meter data for all downstream meters or all meters attached to the selected device
- Ability to determine the configuration of customer owned, automatic transfer switches, or split bus equipment using AMS meters

AMS Based SAIDI

- Meters on every premise – more granularity
- No dependency on network connectivity model
- Meter interval data, outage and restoration notifications, other event data
- Exception management is the key
- Currently being used for a comparison to "normal" SAIDI calculation



Other Use Cases in Place / Validation Phase

- Transformer Overload Damage Prediction
- Transformer Voltage Anomaly Detection
- Transformer Loss of Life Detection
- Feeder Load Forecasting
- Tampering / Theft Detection
- Power Quality

Customer Use Cases In Development

Customer 360 File (C360)	Create customer data repository combining data points on all aspects of the customer experience: Work Requests, Outages, Usage, high bills, predictions of Customer satisfaction and engagements, etc.
Commercial And Industrial Customer Portal (CICP)	Similar to C360: Portal internal groups can reference as a one stop resource for Large C&I customer information. Phase II – Make portal available to Customers for self-service.
Perimeter Threats Geographical Heat Map	Shows worldwide blocked and potential threats blocked by Oncor by geographical area – down to city level.
Service Quality Management (SQM)	Real-time transaction flow dashboard focusing on orders required to be processed in a timely manner (RFNP's). Identify potential non-compliant transactions as early as possible.
Technology & Market Operations Quality Management (TQM)	AMI Network Health Dashboard supporting Machine Learning Models for forecasting and issue detection. Hardware failure prediction and identification of potential impact to Work Requests.
Oncor Data Quality Management (DQM)	Goal is to identify data quality concerns (from replication or application issues) as early as possible based on data relationships, patterns, and shapes.
Application Performance Monitoring Decision Support	Identify and predict application issues that may lead to system outages. Team originally focused on CC&B To-Dos. Currently working to identify other viable scenarios.

High Bill Toolkit

Oncor AMS – Lessons Learned (Challenges)

Business

- Executive sponsorship is a requirement
- Business involvement at all levels is a requirement
  - Need their “buy-in”
- “All” business processes will be impacted by AMS
- Try to get dedicated business resources
- Make sure they are involved with business requirements
  - How will AMS impact day-to-day operations
- Do not forget to involve IT SMEs with requirements
  - Network and server procurement
- Simultaneous operation of manual and AMS

Communications and Customer Education

- Social Media – inexpensive but permanent, expect "uglies"
  - Negative responses lend some credibility
- Traditional Advertising – expensive, can be hard to track
- Mobile Experience Center (MEC) – transportable, physical
- Door Hangers
- "Ask Oncor" program
- Fast customer response
- Don't forget internal customers
- Managing perceptions
- Focus on the customer!

Documentation and Process Management

- Document, document, document
- "All" business processes will change
  - Many new documents will be developed
    - Business requirements
    - Business processes
    - Technical documentation
    - Strategic architecture & policy standards
    - SOPs
    - Job aids

- Expect hundreds and hundreds of new documents
- Do not forget the long term maintenance and as-builts of docs

Meter Deployment

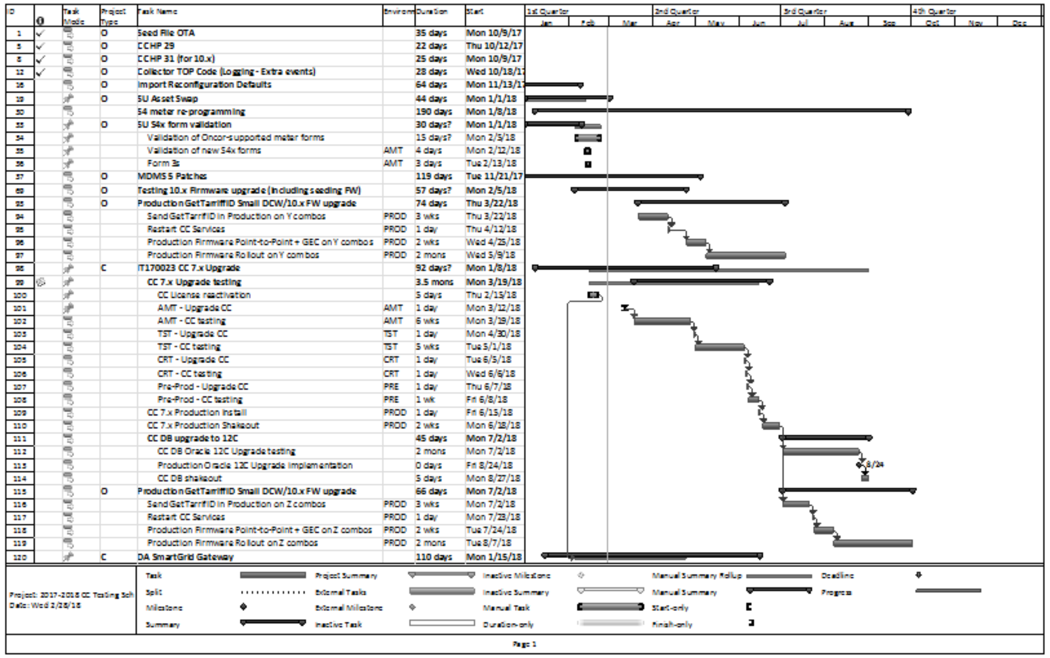
- Installers, employees or contractors
- Take pictures of meter out reads
- Let the customer know when you are coming
  - Coordinate with Corporate Communications
- Determine when IT has to be in place (before, during, post)
- Take it slow, make sure processes support deployment
- Plan for tampering, “increase” your expectations
- Hire an electrician
- Plan for denial of access
- Get the GPS coordinates

Network Deployment

- Construction and installation - employees or contractors
- Make multiple engineering standards – one size does not fit all
- Plan for future RF design
- Deploy ahead of meters
- Expect complaints with RF interference
- Do not forget underground areas!
- Topology

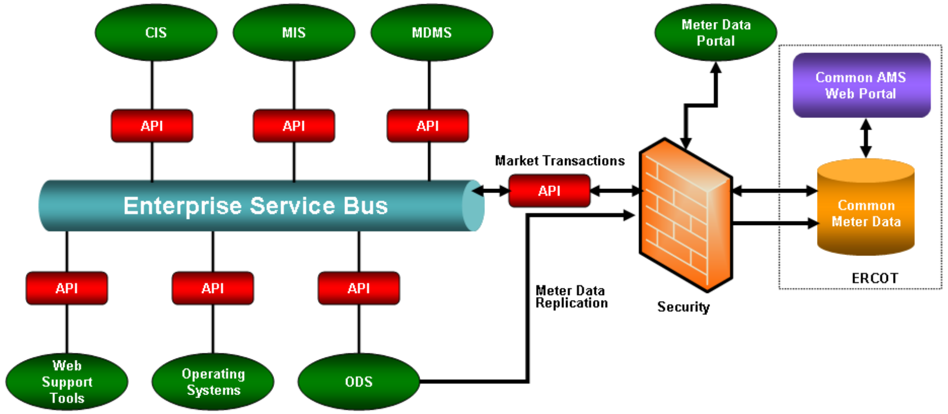
Resource Planning

- Review your business organization
  - Jobs will change
  - New and changed skill sets
- SMEs – use contractors but move to internal ASAP
- Engineering and construction needs
- Installers
- Field Service Reps
- RF Technicians
- Business analysts
- Systems Integrator
- Any new tools needed?
- AMS is not just a technology upgrade!



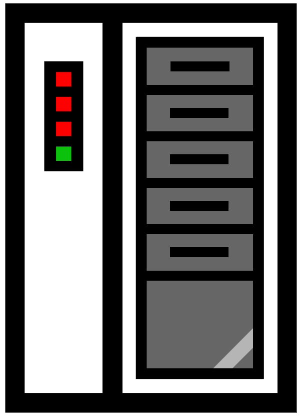
Information Technology – Software & Services

- Consolidate project facilities
- Integration with legacy systems
- Expect many releases
  - Technology still new / immature tech
  - Create detailed implementation plans
- Try to minimize software customization
  - Use core or off the shelf
  - Change the interfaces
- Do not underestimate IT costs



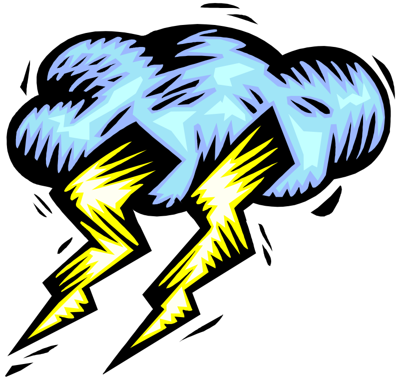
Information Technology – Infrastructure

- Define your infrastructure, interim vs. final production specifications (scalability)
- Network is critical – bandwidth, bandwidth, bandwidth
- Revisit your testing strategy and environments
- Not a typical IT integration, like SCADA
  - Use live meters (& RF equipment) in testing
- Keep application vendors involved in system builds
- Storage and proper tiering of storage is critical
- Remember the backup solution
- Data center becomes part of the central utility
  - IT department is not just a support organization
- Volume of data – millions and millions of lines of data



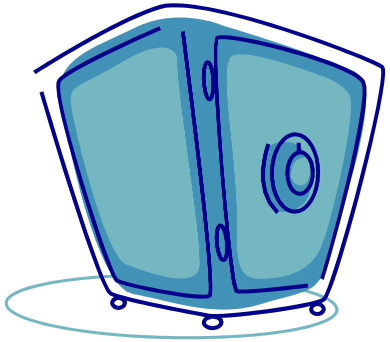
Information Technology – Testing

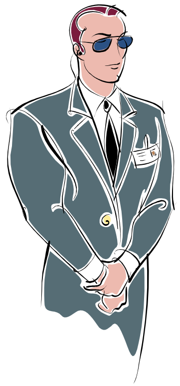
- Define and control testing scope
- Configuration management of environments
- Defect management - expect bugs
- Set realistic completion dates
- Create a detailed testing plan
  - Meters, network equipment, HAN, UAT
- Expect many releases
  - Technology still new / immature tech
  - How will device firmware impact testing
- Create detailed implementation plans
- Take care of your people – “storm mode”



Security

- User roles and responsibilities
- Access control
- Physical security
  - Collectors in substations
  - Meter locking bars
- Cyber security
  - Encryption
  - Penetration testing - RF and IT
  - Defense and monitoring of backhaul
- Data privacy
- Industry standards / regulatory requirements – NERC CIP
- State of the art, end-to-end security is complex – and expensive





Home Area Networks (HAN)

- Testing and demonstration programs
  - Firmware (meters & devices)
  - HAN related functionality
  - UAT – API testing
  - Tools and skill sets
- Device validations
- HAN Support – internal and vendor
- REP Programs
  - Information access
  - Partnerships
- Do not forget the call center!

Operations

- Fraud, tampering, and revenue security
- Exception handling and error processing
  - Problem resolution and tracking
- Controls, monitoring, and reporting
- Network monitoring
- File synchronization
- Firmware rollouts
  - Plan, tracking, when are you done
- RF interference – broadcast
- How many analysts does it take to replace 350 meter readers?

Market, Regulatory, & Industry

- Market and customer expectations will change
- Regulatory requirements will change
- Stay involved with industry standards
  - Still being developed – keep up
- Maintain good Surcharge documentation
  - Budgets and accounting
- Are you ready for AMS to be NERC CIP (do you treat like DSCADA)?

Final Comments

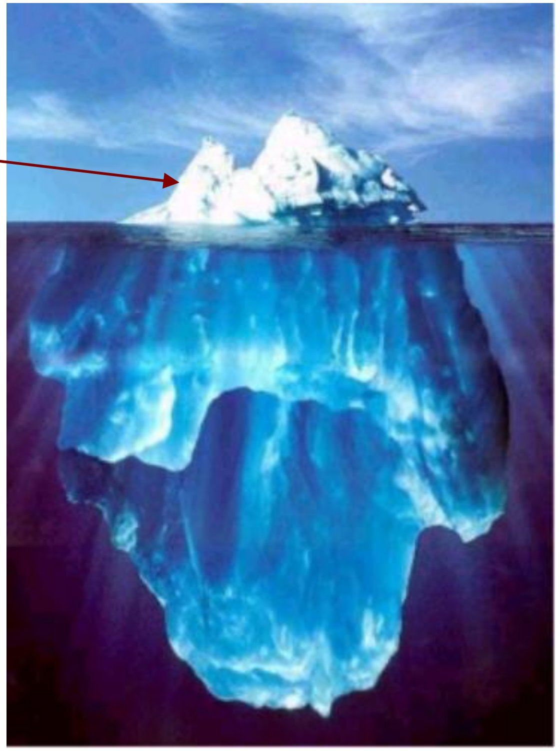
- It is never a good time to start a new, big change
  - Customers will complain
- Don’t run from the problem; hit it head on
  - Bad news doesn’t get better over time
- As well as a process appears to be working, expect human error
- Technology is not necessarily less expensive
- Start with the big exceptions and work your way down
- Be flexible
- Don’t tug on Superman’s cape

Key Message/ Takeaways

1. AMS is the enabler
2. Automation is the key
3. New visibility into systems
4. Trust the data

Thank You

We are here



An Advanced Metering System (AMS) brings a lot more than just the ability to read meters remotely. AMS enables a whole new set of data that can be used for engineering analysis and provide for new ways to improve a distribution system's efficiency and reliability.