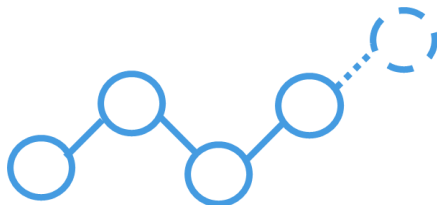




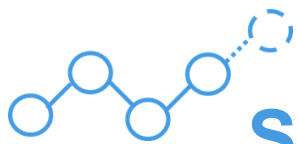
Big Data and Machine Learning for Clean Coal and Carbon Management Strategic Initiatives

S.A. DellaVilla Jr.



ORAP[®]

The Foundation for Predictive Analytics



SPS – Data First



Power, Platforms, Pipelines



Reciprocating Engines



Renewables...Wind & PV

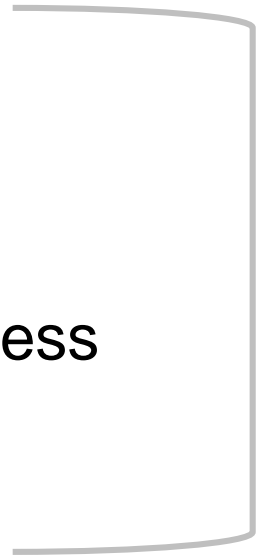
ORAP[®] - A Global Database

RAM Data for Product & O&M Improvement



Today: A Competitive Global Market

- Efficiency
- Operational Flexibility
- Durability
- Environmental Friendliness
- Reliability

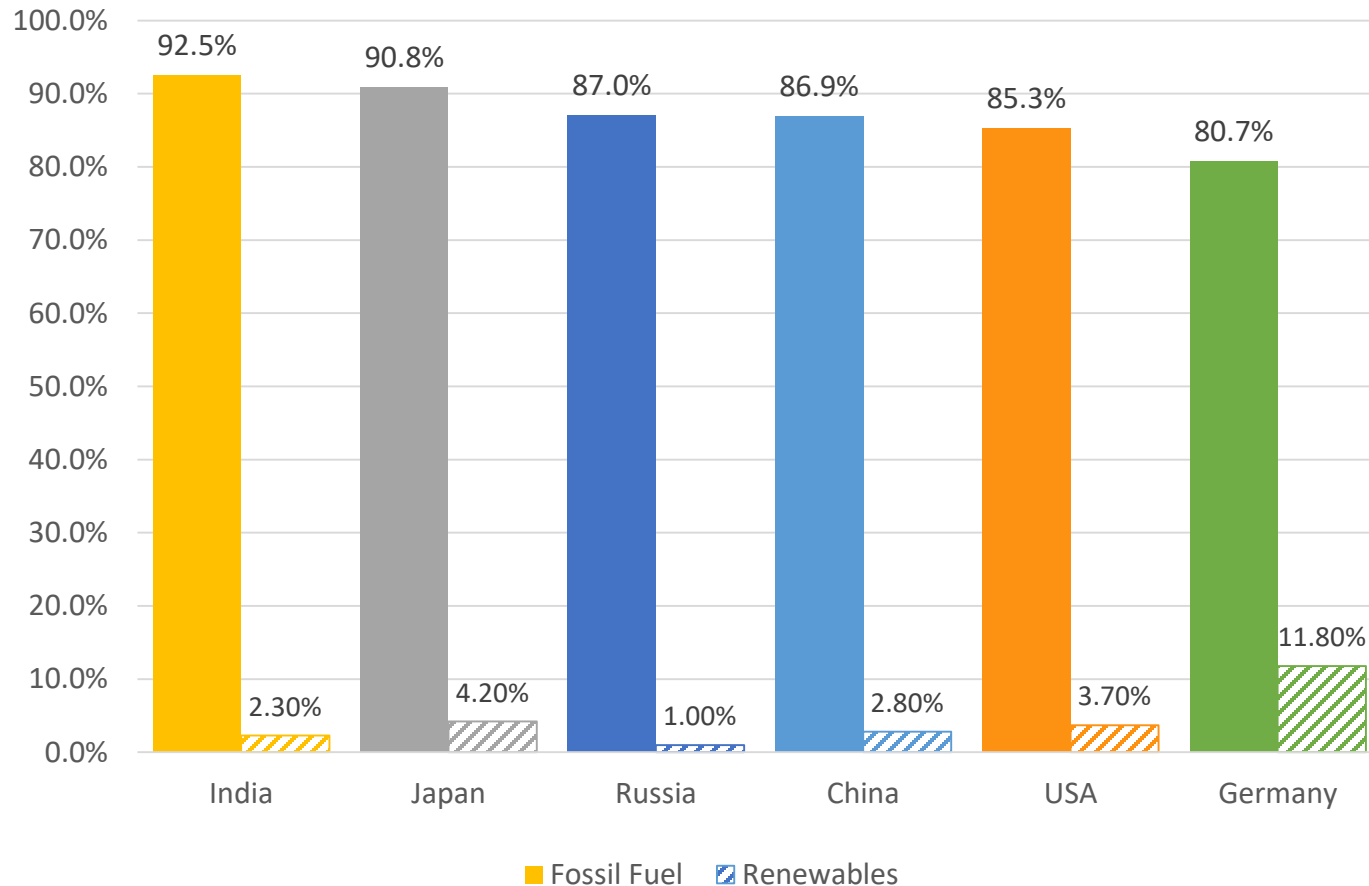


**Market Requirements
Drive OEM Design**

Impacts O&M – Data Is Required



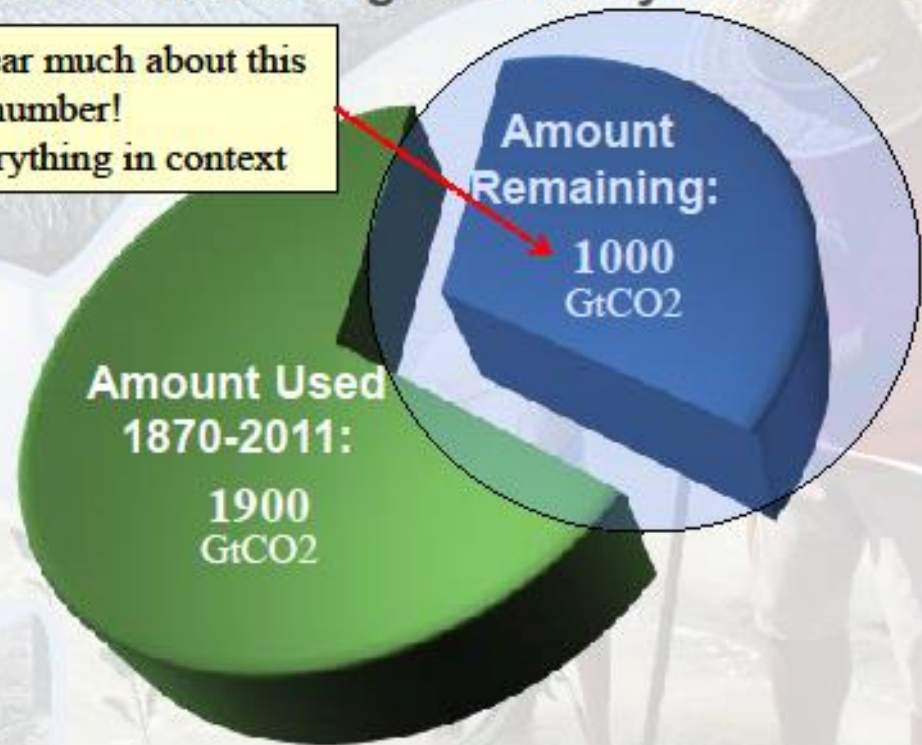
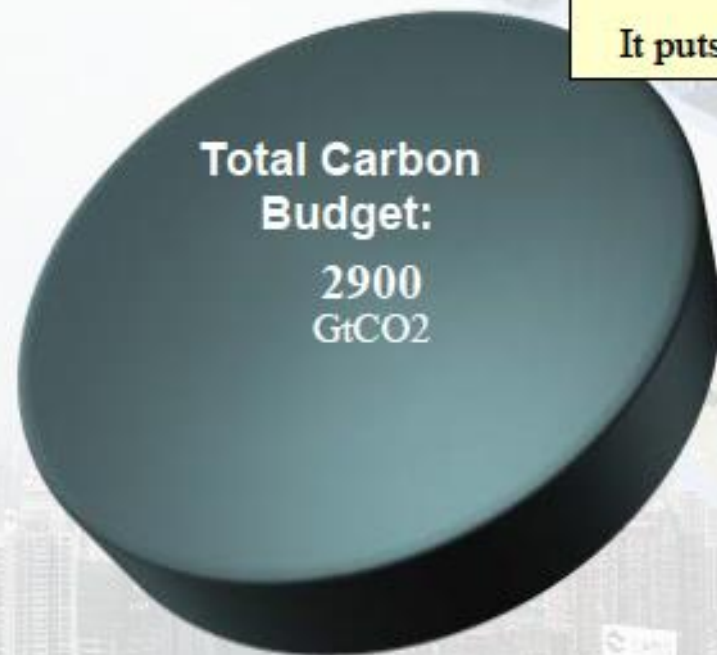
Generation Sources – Fossil Fuels & Renewables



The window for action is rapidly closing

65% of our carbon budget compatible with a 2°C goal already used

We don't hear much about this number!
It puts everything in context



AR5 WGI SPM

base

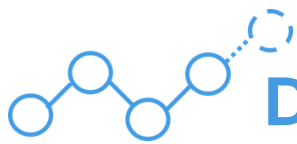
IPCC AR5 Synthesis Report

"Practical Strategies for Emerging Energy Technologies"

ipcc

climate change

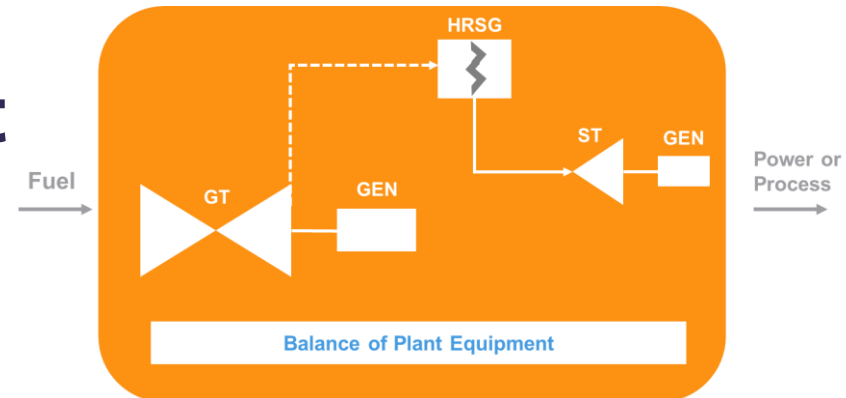




Data & Analytics Always Drives Technology Advance - It's What Got Us Here

- What Kind of Data?
 - Test Data
 - Field Data
 - Monitoring & Diagnostics
- Data Fusion™ – Makes the Difference
 - Transformation
 - Analytics

Must be Across the Plant

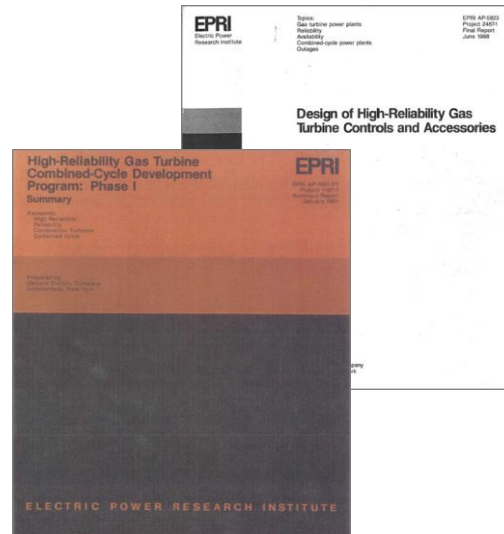




Field Data – DOE & EPRI Investment

- Significant Investment in Reliability Improvement Programs...ORAP Supports

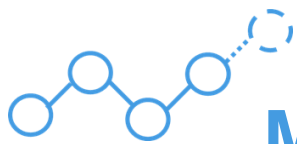
Clear that data was more than just about the “average”



Analytical Techniques

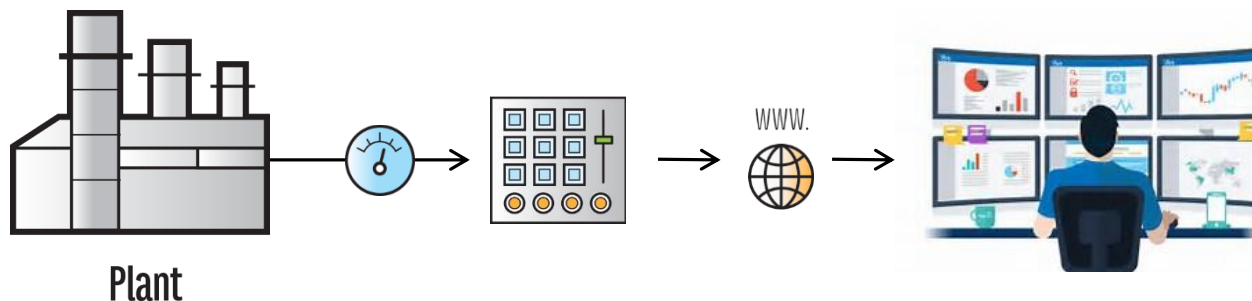
- Weibull Analysis
- Reliability Block Diagram (RBD)
- Failure Modes and Effects Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Markov Simulations using Binomial Models
- Analysis of Variance

Glide Path to “Big Data” and “Predictive Analytics”



Monitoring & Diagnostics

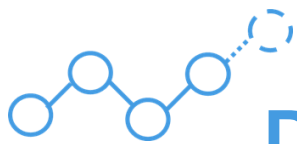
- In 90's M&D Used as Approach for Mitigating Risk in New Technology Introductions
- Operating Assets Seen in “Near Real-Time” by OEM and Third-Parties Using M&D
- Subject Matter Expertise – Performance Engineers Combined with M&D (Not Scalable – Not Fast Enough)





Monitoring & Diagnostics

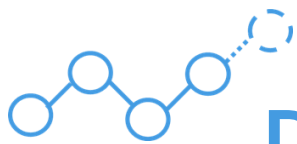
- Data from M&D Must be Fast & Furious to Have Real Effect
 - Ongoing stream of data points in seconds, milliseconds
 - Speed, vibration, temperature, pressure, alarm and trip limits
- Issues
 - M&D is less valuable and not scalable without analytics, subject matter expertise, & knowledge – **APR, ML, SME Essential Ingredients**
 - M&D does not adequately focus on the Total Plant Systems
 - Owner/Operators not just concerned about the GT, but the whole plant
 - Pedigree of the plant must be clearly understood
- Unless Action Can Be Taken at the Plant, M&D is of Limited Value
 - How quickly is the issue or fault developing? How quickly can something be done about it?



Data Fusion™ – A Key Goal

- **Data Fusion** = Where Near Real-Time Data Transformation Supports Owner/Operators in Validating and Monetizing Efficiency, Operating Flexibility, Durability, Environmental Friendliness, & Reliability
- Key Transformations: Time, Capacity, Age, and Events (the Operating Cycle)
- M&D is Precursor

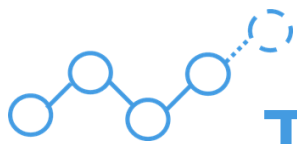
Transformation & Analytics



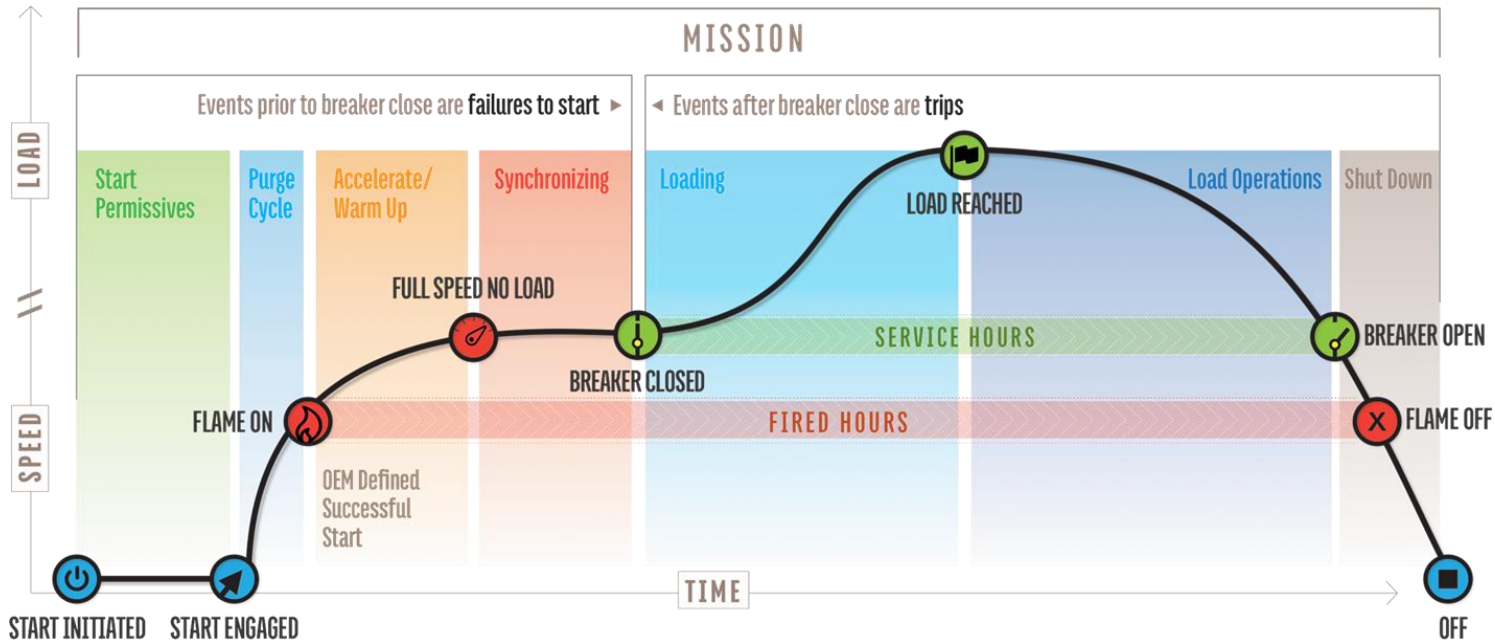
Data Fusion – The Operating Cycle

- Strong Focus on Operating Cycle or Mission Profile of the Unit
- Driven by Economic Dispatch Requirements
- Market is placing more stringent requirements on gas turbines (i.e. rapid starts and ramp rates)
 - Focus on mapping RAMD and near real-time performance data to drive economic payback
 - First Principles Models, APR, ML, & SME

Requires Speed, Fidelity, Transformation & Productivity



The Full Cycle – The Data is There Now



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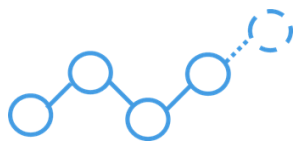
(in minutes)	Start to Flame	Flame to Full Speed	Full Speed to Breaker Closure	Total Start
AERO	3	1.7	1.5	6.2
“E” Class	8.4	8.6	.2	17.2
“F” Class	13.3	6.8	2.3	22.4
“G” Class	8.3	15.4	6.2	29.9

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(in hours)	Breaker to Trip
AERO	144
“E” Class	8.2
“F” Class	68.6
“G” Class	127.1

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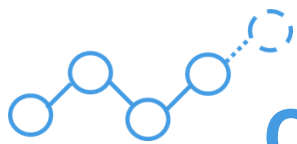




The Right Combination of Technologies for On or Off Grid Change

- Clean Coal with Carbon Sequestration (more than just Enhanced Oil Recovery)
- Renewables (meeting demand with increased capacity factors)
- Battery Storage (increased life and run times)
- Hybrid – Natural Gas Combined Cycles with battery to support fast start-ups and ramp rates (with low emissions and high efficiency)
- Hybrid – Natural Gas Combined Cycles with Renewables (wind and or solar)
- Hydrogen fuel for Combined Cycle systems
- Combined Heat & Power (higher levels of efficiency and low emissions)

Real Data with Verifiable Analysis is Required



Conclusion

- Technology & Market Uncertainties Add Up to Operational Risk
 - Influence profitability and margins
- Essential to Characterize These Risks in Terms that Have Meaning
 - Easily understood so they can be controlled
- Fusion of Data with Analytics Provides Near Real-Time KPIs of Plant Performance: Measures of Success or Failure
- Effective Plant Operations and Profitability Demands Decision Support
 - Relies on instantaneous access to available information

Data Fusion