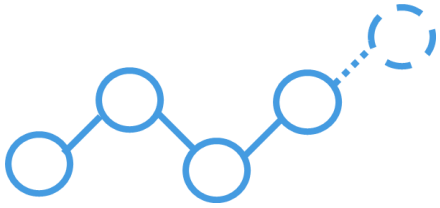

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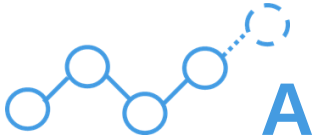
A Data Review & Assessment

European Turbine Network

9th International Gas Turbine Conference 2018



An Overview in a Dynamic Market

- Who is SPS?
- What Does the ORAP Data Show Us?
- Where Are We Headed – Data and Predictive Analytics
  - Asset Insight™
  - Data Fusion™
  - DOE Projects

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SPS – Data First

Power, Platforms, Pipelines

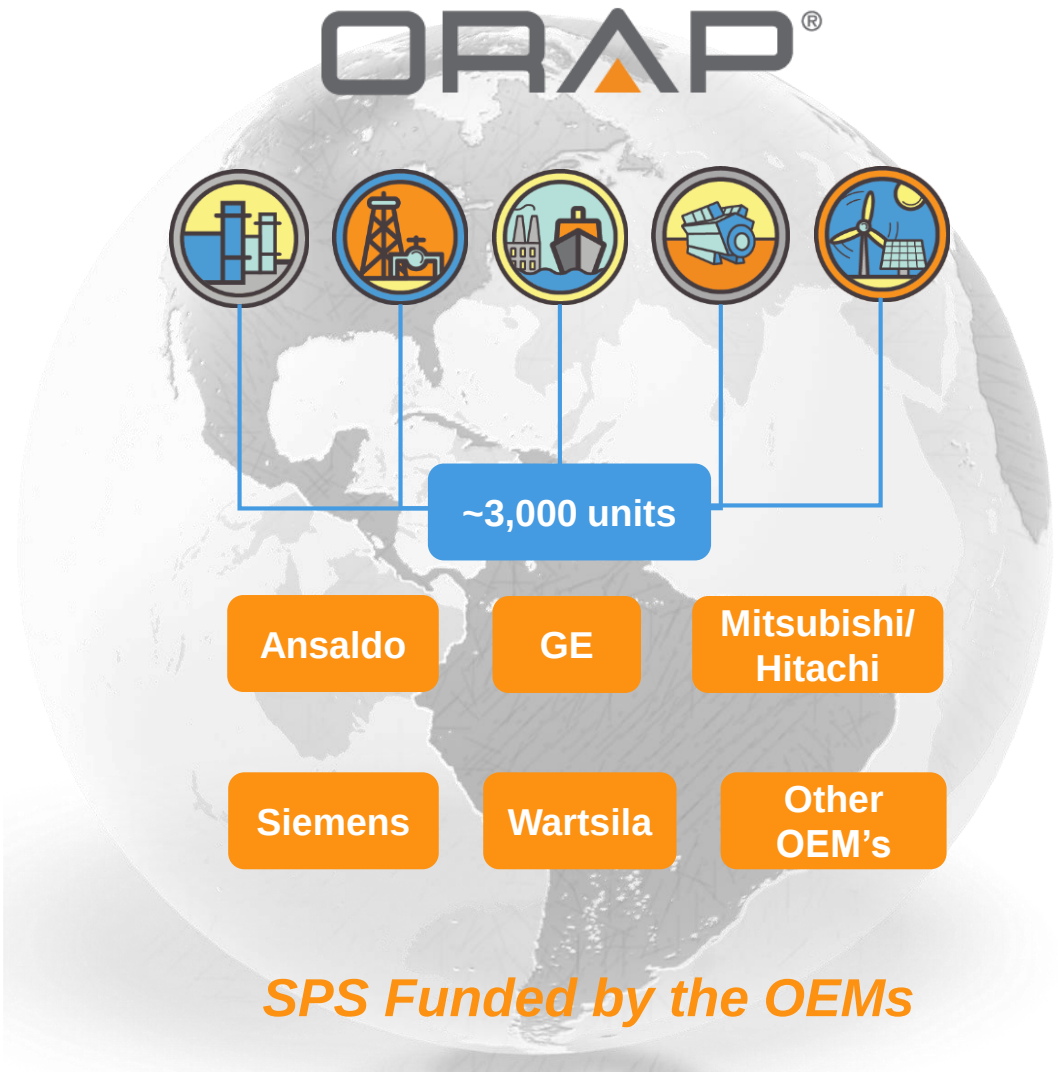
Reciprocating Engines

Renewables…Wind & PV

ORAP® - A Global Database

RAM Data for Large-Scale Capital Equipment

ORAP: The Foundation for Predictive Analytics



- Third-Party, Unbiased
- 30+ Years of Data
- RAM Data for Large-Scale Capital Equipment
  - Heavy Duty & Aero GT
  - Fossil ST
  - Reciprocating Engines
  - Renewables
- Technologies & Applications
  - Combined & Simple Cycle Plants
  - Power Generation & Mechanical Drive
  - Peaking to Continuous Duty
- IEEE Standard 762 Compliant

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Gas Turbine OEMs and Models

Driven by Technology Advances

Vintage Technology

GE
MS5001
MS5002
MS6001B
MS7001ABC
GT8/8B
GT9
GT11D
GT13D

Siemens
W251
W501A/B
SGT-700
V64.3

"E" Class

Ansaldo
AE 94.2

GE
MS7001E/EA
MS9001B
MS9001E
GT8C
GT11N/N1
GT11NM/N1M
GT11N2
GT13E/E1
GT13E2

Hitachi
H-25
H-80

Mitsubishi
M501D
M701D

Siemens
W501D
SGT-800
SGT5-2000E
SGT6-2000E
SGT6-3000E
W701D

"F Class"

Ansaldo
AE 64.3A
AE 94.3A
AE 26

GE
MS6001F/FA
MS7001F/FA
MS9001F/FA
MS7001FB
MS9001FB
GT24
GT26

Mitsubishi
M501F
M701F

Siemens
V84.3
SGT-1000F
SGT5-4000F
SGT6-4000F
SGT6-5000F

"G" Class

GE
MS9001H
MS7001H

Mitsubishi
M501G
M701G
M501GAC
M701GAC

Siemens
SGT6-6000G
SGT5-8000H
SGT6-8000H

"Advanced Class"

Ansaldo
AE 36

GE
MS7001HA
MS9001HA

Mitsubishi
M501J
M701J
M501JAC
M701JAC

Siemens
SGT5-9000HL
SGT6-9000HL

Aero <40MW

GE
LM1600
LM2500

Mitsubishi
FT4
FT8

Siemens
SGT-A05
SGT-A20
Industrial Olympus
SGT-A35

Aero >40MW

GE
LM5000
LM6000

Mitsubishi
FT4000

Siemens
SGT-A65

Note: LMS100 outside these MW classifications

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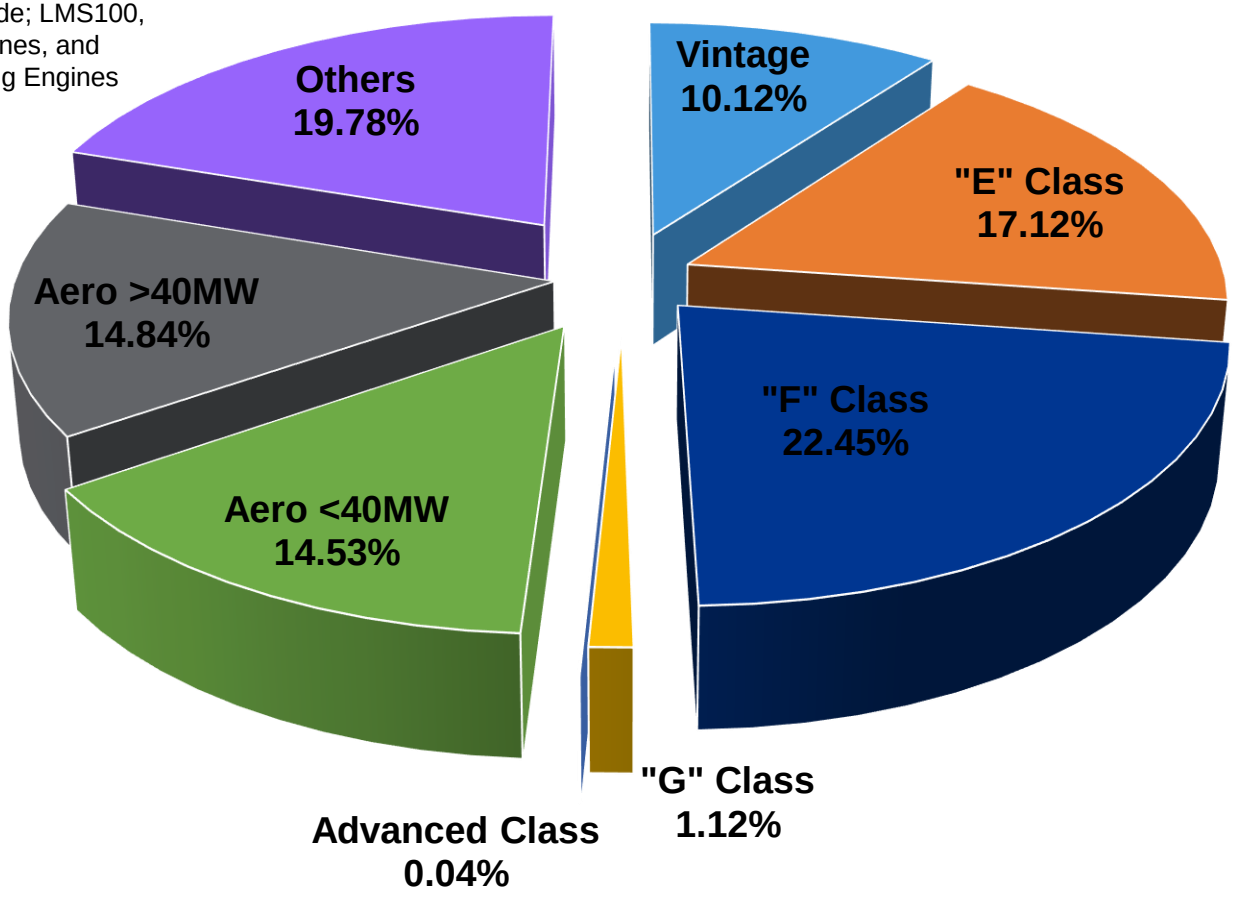
Units in ORAP

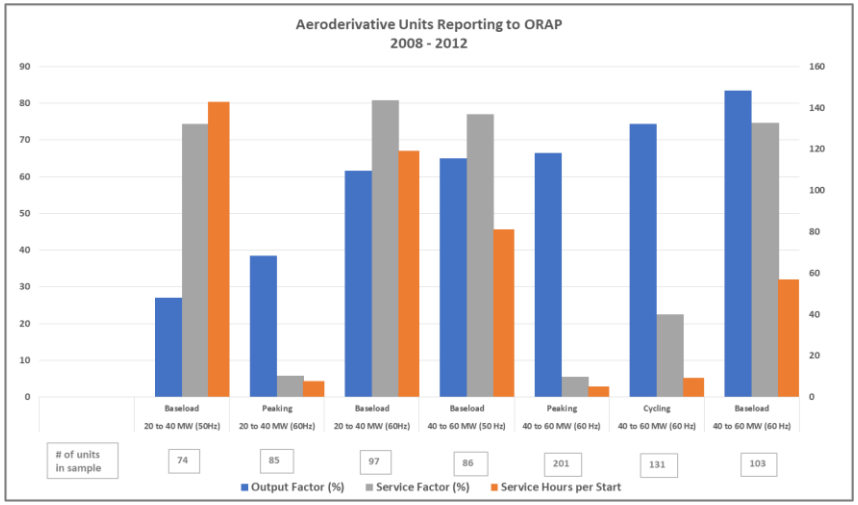
Others include; LMS100, Steam Turbines, and Reciprocating Engines

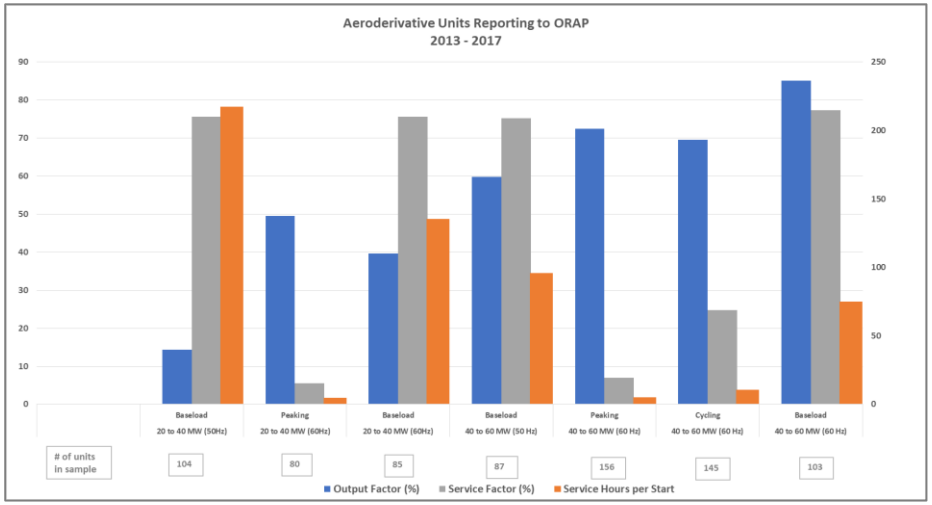


What Does the ORAP Data Show Us?

- Reviewed 3 Time periods:
  - 2008 – 2012
  - 2013 – 2017
  - 2018 Year to Date
- Samples included:
  - Aeroderivative Units 20 MW to 40 MW
  - Aeroderivative Units 40 MW to 40 MW
  - “E” Class Units
  - “F” Class Units
  - “G” Class Units
- Samples further segmented by
  - Grid Frequency
  - Duty Cycle
- Following Slides Highlight Review of Aeroderivative and “E” & “F” Class units

ORAP Data – Aeroderivative Units





Aeroderivative 20 to 40 MW Units from 2008 – 2012

- Units in 50Hz applications serve mainly Baseload Duty with average missions of ~6 days and annual operation +6,500 hours
- Units in 60Hz applications are largely split between Peaking Duty with average missions <8 hours and annual operation ~500 hours and Baseload Duty with average missions of ~5 days and annual operation +7,000 hours
  - Peaking Duty units are largely in Utility applications, while the Baseload Duty Units are mainly in Industrial Cogeneration & CHP applications.

Aeroderivative 40 to 60 MW Units from 2008 – 2012

- The units in 50Hz applications are mainly in Baseload Duty similar to the 20 MW to 40 MW units. The average mission time is less at ~3.5 days, but annual operation increased to +6,700 hours
- There are a large number of units operating in Cycling Duty for 60Hz Applications. These units start over 200 times per year

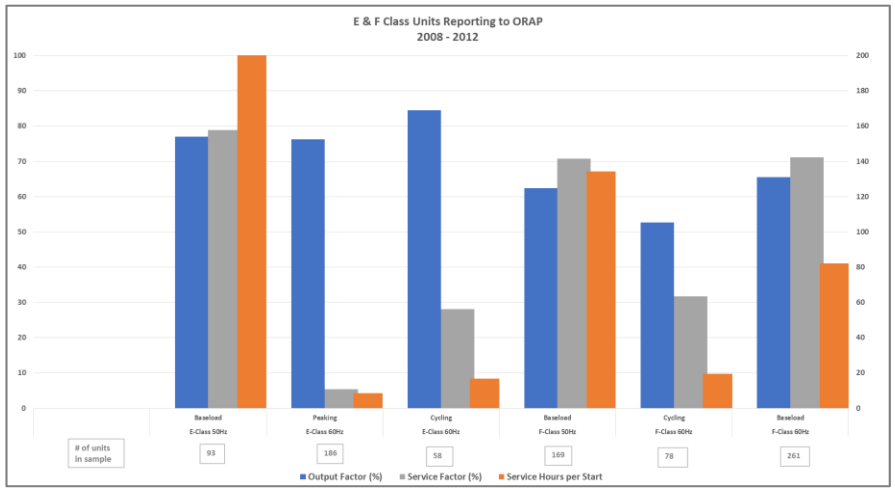
- When Comparing Time Frames from 2008-2012 to 2013-2017, the average mission time increased across all Aeroderivative fleets while the average annual operating hours remained consistent

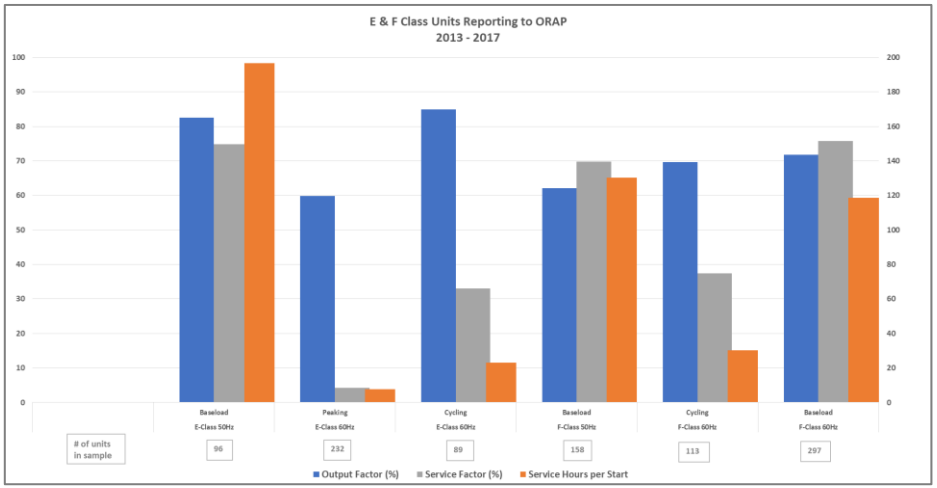
  For example the 20 to 40 MW Baseload Duty units:

  - The average mission increased from ~6 days to +9 days for the units in 50 Hz applications and from ~5 days to +5.5 days
  - Output Factor decreased over same time period – this is an indications that the Units are load following to a large degree in the last five years

- The data covering YTD 2018 has remained consistent with 2013-2017

ORAP Data – “E” & “F” Class Units





Heavy Duty E Class and F Class units

- In the 50Hz Market, the majority of the Heavy Duty E Class and F Class units reporting to ORAP operated in Baseload Duty For both 5 year periods 2008-2012 and 2013-2017
  - These Units operated on average between 6,100 and 7,000 hours per year with average missions ranging between 5 and 11 days
- The majority of the E Class units reporting to ORAP in the 60Hz market operated Peaking Duty with average annual operation <500 hours and ~8 hour missions
- The majority of the F Class units reporting to in the 60Hz market operated Baseload Duty with average annual operation ~6,500 hours and missions between 3 and 5 days

- E & F Class Cycling duty units in 60Hz applications operated more frequently and for longer missions when comparing 2008-2012 to 2013-2017. Average annual operation increased by ~440 hours for the E Class fleet and ~500 hours for the F Class fleet
- The data covering YTD 2018 has remained consistent with 2013-2017

ORAP Data – Forced Outages Major Contributors

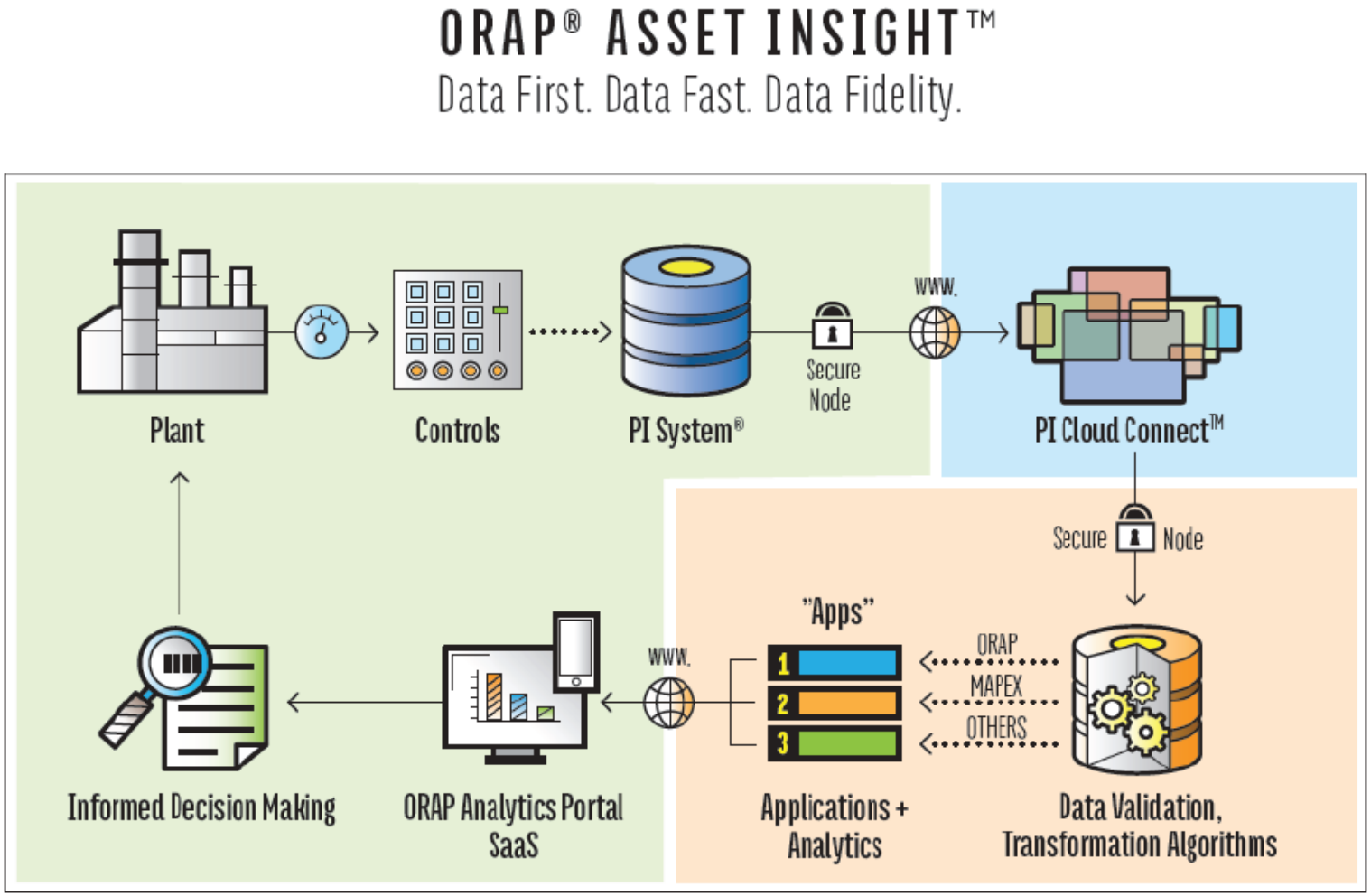
2008-2012

- For 20 to 40MW Aeroderivative Units (50Hz and 60Hz)
  - Power Turbine First Stage Vane problems; 22 events with average of +180 days of downtime per event
- For both 20 to 40MW & 40 to 60MW Aeroderivative Units (50Hz and 60Hz)
  - Grid Instability; Over 1,100 events with ~6.5 downtime hours per event

2013-2017

- For “E” Class Units (50Hz and 60Hz)
  - Main Transformer; 90 events with average of +2 weeks of forced downtime
- Significant downtime for “F” Class Units (50Hz and 60Hz) also
  - Main Transformer problems; 80 events with average of +2 weeks of downtime
- 107 Forced Events reported on the Engine Bearings for 40 to 60MW Aeroderivative units (50Hz and 60Hz), average of +200 downtime hours per occurrence
- “F” Class Combined-Cycle Plants (50Hz and 60Hz)
  - 120 Forced Events reported on HP Drum Issues, average of +3 hours of downtime, mainly drum level trips

Architecture Overview



ORAP Asset Insight ‘Apps’

ORAP RAM Connect	Benchmark Your Reliability Performance Against Your Peers
ORAP GADS	Simplify the Process of Submitting your NERC GADS Required Data
Life Calculator	Automatically Track the Cumulative Life of your Equipment Using Embedded Logic - Adhering to the Complex Aging Algorithms and Calculations Defined by the OEM
Operating Profile	Record Each Mission, from Start-Up to Shutdown, including All Major States – as well as Tracking Fuel Used and Power Produced at Each Stage
Maintenance Forecast	Project Your Major Maintenance Requirements up to 20 Years. Be Predictive About When you Will Need to Perform Maintenance, Based on Your Plant’s Actual Operating Data
RAM KPIs	Calculate and Report Standard KPIs Required by Asset Management, Financial Management, Regulatory Authorities, and Insurance Companies
MapEx®	State-of-the-Art Thermal Performance Monitoring System to Support Decisions that Optimize Asset Utilization
PlantTrack™	Inspect, Repair, Replacement – Continuous Assessment of Critical Locations in Steam Systems – Structural Integrity
PredictIt™	Predict-It: Real-time anomaly detection software utilizing advanced pattern recognition

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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

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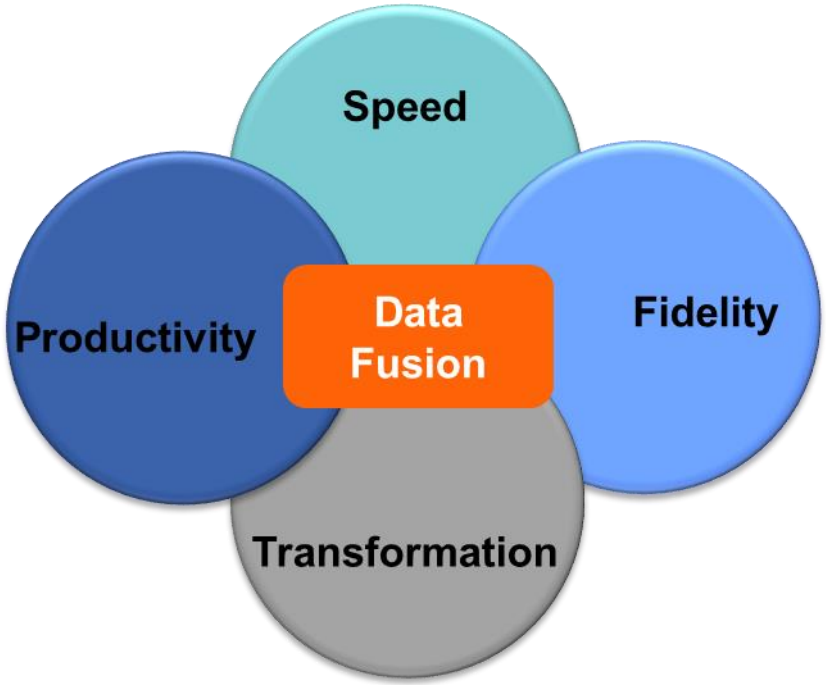
Data Fusion – Key Elements



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

Requires Speed, Fidelity, Transformation & Productivity

Data Fusion – US DOE Projects

- Utilizing High Performance Computational Analysis to Characterize the Operating Envelope of Various NGCC Operating Technologies – Quantifying Efficiency, Availability, and Durability of Critical Hot Gas Path Hardware and Assessing the Impact on other Downstream Systems or Components across Cyclic Operating States
  - Oakridge National Labs
- An Investigation of the Effect of Cyclic Operation on HRSG and Coal Fired Boiler Tubes – Failures Induced by High Thermal Stress and Component Fatigue – An Opportunity for Predictive Maintenance
  - National Energy Technology Laboratory (NETL)

A Conclusion in a Dynamic Market

- Market Places Premium on Mitigating Uncertainty
  - Uncertainty: What is the Likelihood that...?
    - Plant is deterred from meeting dispatched load because it could not successfully start, or not start “fast enough”
    - Replacement source of power is needed because the plant cannot successfully complete its operating mission due to a trip from load
    - Changes in operating duty affect the planned maintenance schedule, part replacement strategy, and overall maintenance costs
    - OEM increases the interval between inspections and risk needs to be taken on by the plant
    - Operating efficiency and performance cannot be maintained
    - Pro forma expectations for profitability are missed because anticipated operations and maintenance plans are not met

Who Picks Up the Operational Risks?
How Do you Mitigate the Risk?

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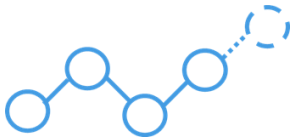

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