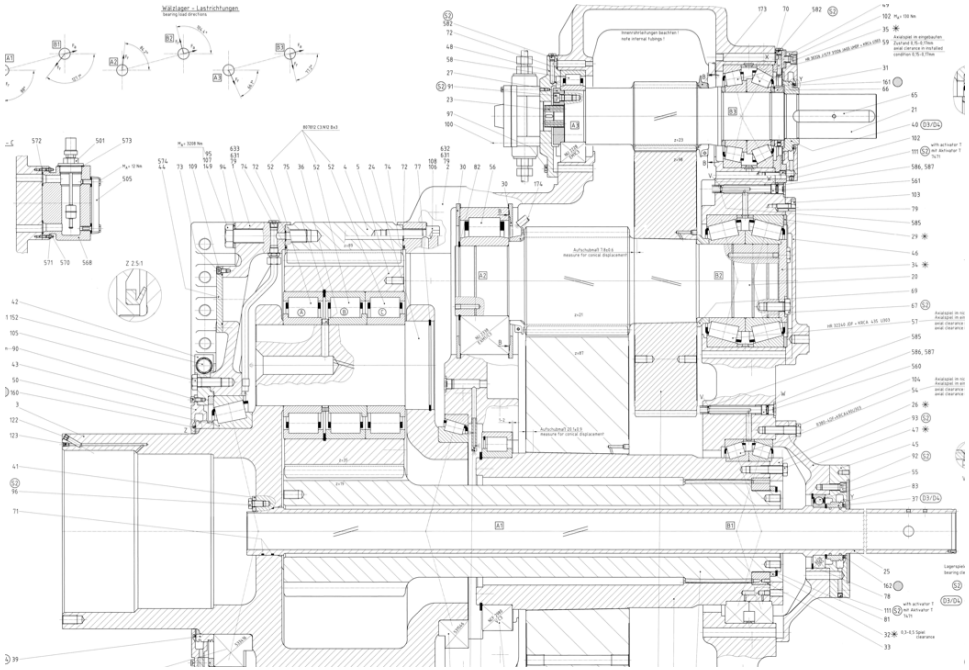
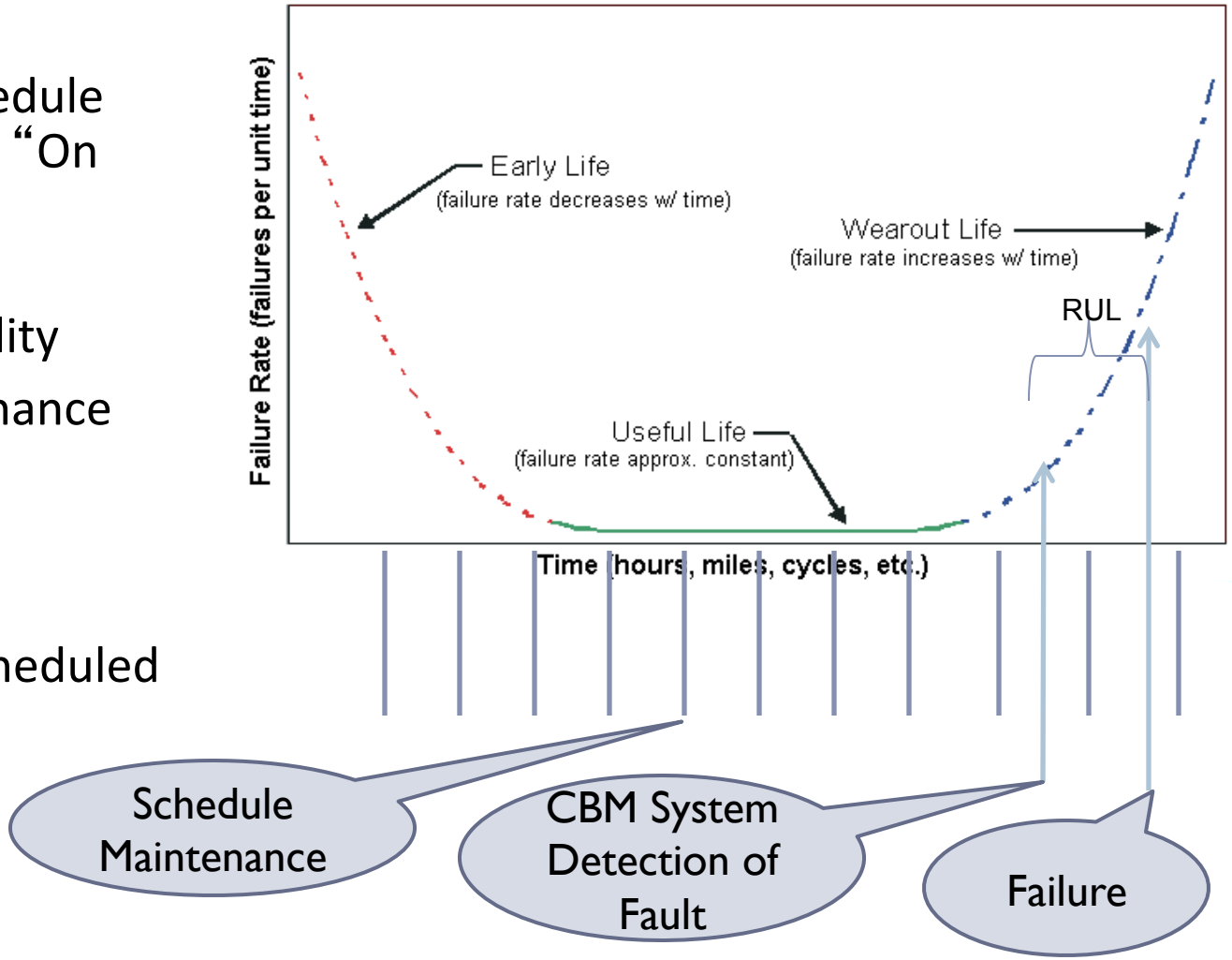


Lowering the Cost of Projects

Eric Bechhoefer

The Promise Of On Condition Maintenance

- Move from Schedule Maintenance to "On Condition Maintenance"
- Improve Reliability
- Reduce Maintenance Cost
- Reduce Logistic Footprint
- GOAL: No Unscheduled Maintenance!



Low Cost CBM System with Best in Class Performance

- Why is CBM Not Ubiquitous?
  - OEM Standard Offering
  - O&M Retrofit?
- System Cost is Unattractive
  - Owners Can't Make the Cost Benefit
    - Initial Purchase Price
    - Installation and Commissioning
    - Knowledge Creation
- Need to Change the Equation
  - Lower Costs
  - Improved Functionality
  - Simple User Interface

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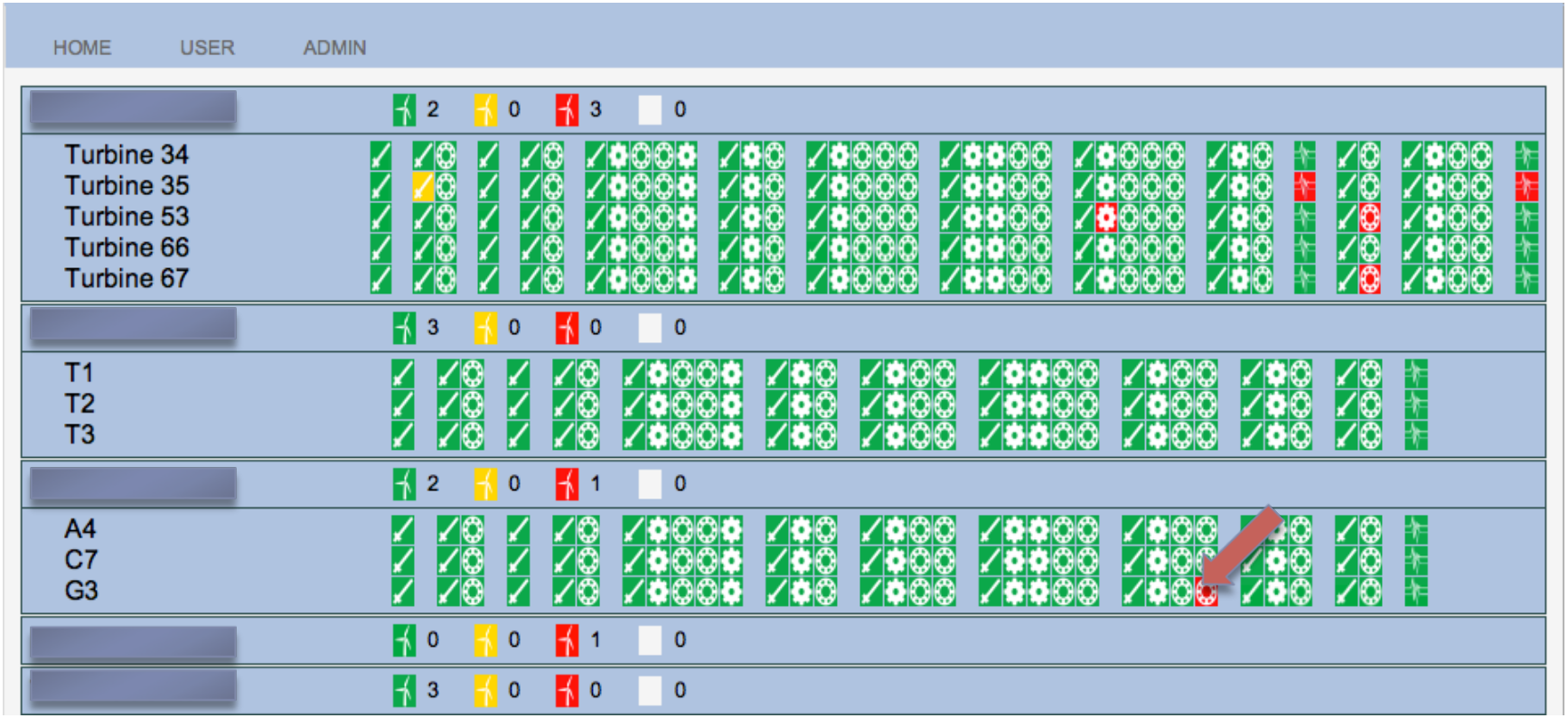
RENEWABLE NRG SYSTEMS

What is Prognostics, And Why

- Estimate an Remaining Useful Life
  - Not Time to Failure, But Time Until Its Appropriate to Do Maintenance
    - Continued Operation Will Reduces the Reliability of the System
    - May Cause Collateral Damage to Other Components
- A Logistics Support Tool
  - Better Manage Assets for Maintenance/Deployments
  - Manage the Supply Chain
- Allows Maintainers to Better Leverage CBM Information

Fleet View: Select and Explore



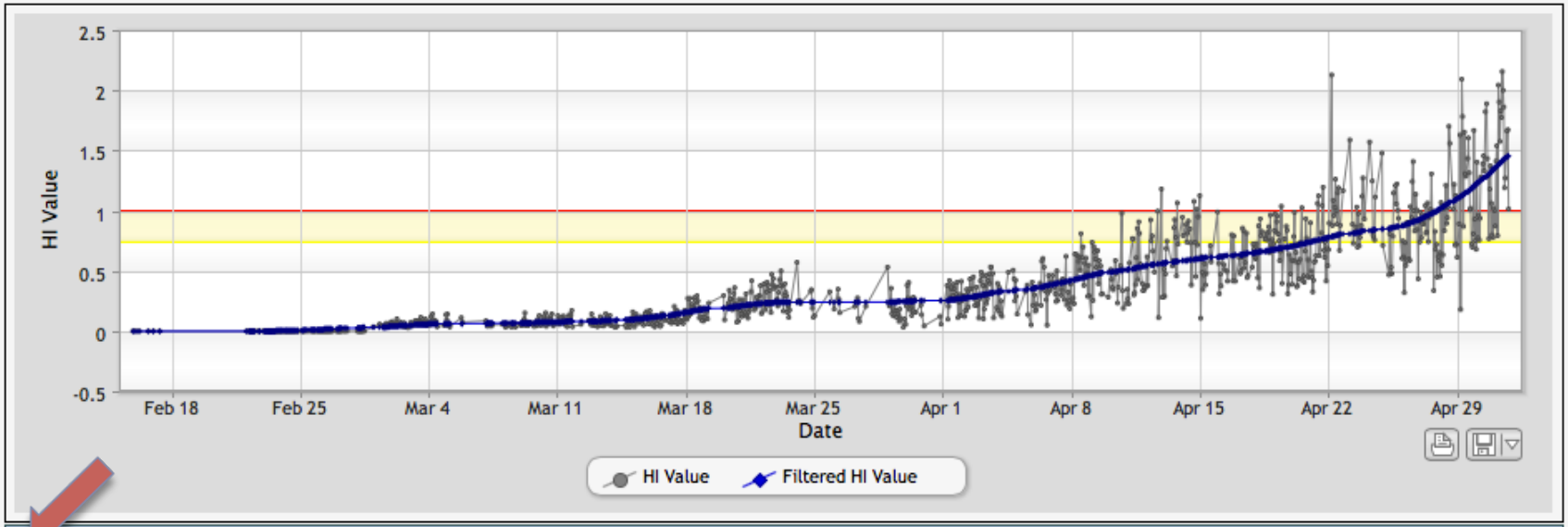
HI Trend and Alerts

(•) Active Alerts ( ) All Alerts

Clear	Active	Locked	Severity	Date	HI	RUL	Cleared Date	Cleared By
Clear	True	False	Alarm	4/29/2013 9:22:09 AM	0.99047102585647	0		
Clear	True	False	Warning	4/19/2013 11:21:31 AM	0.752200411861379	0		

▲ HI Trend

Select HI Fields To Display Start : 2/15/2013 End : 5/1/2013 Update

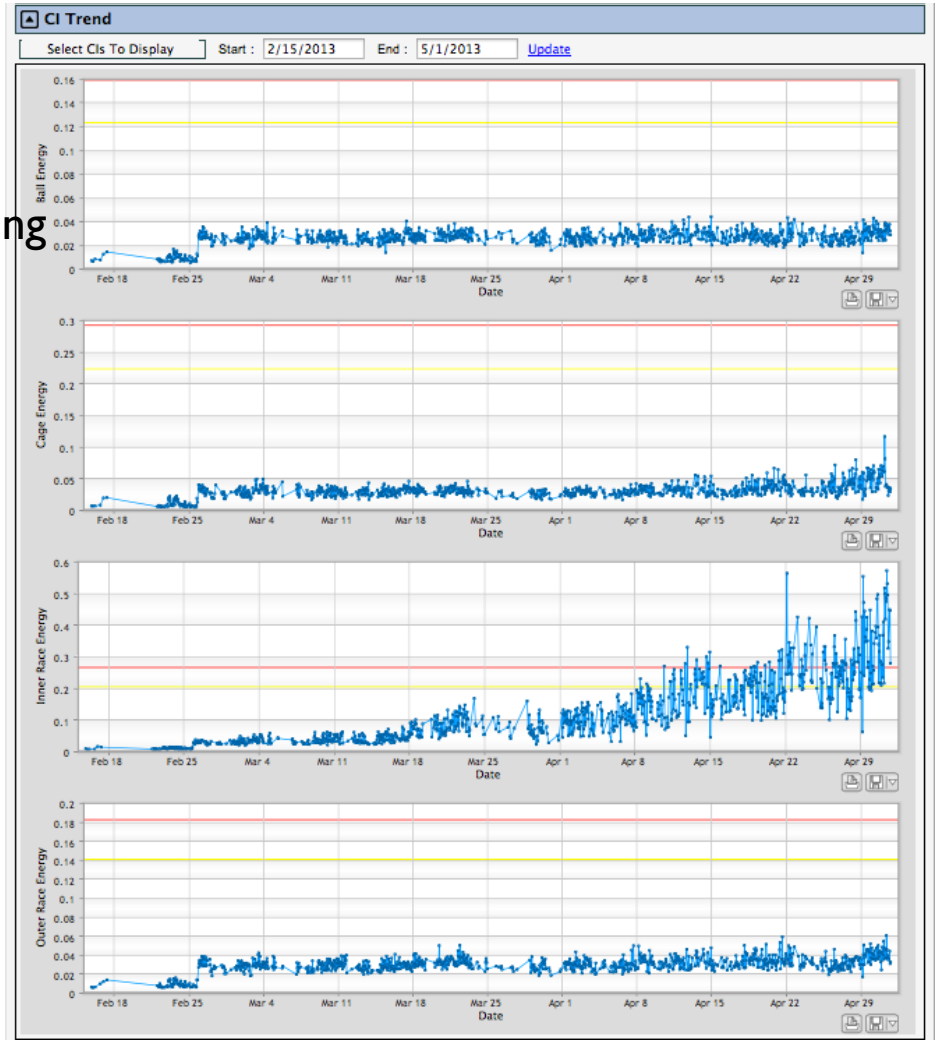


▼ CI Trend

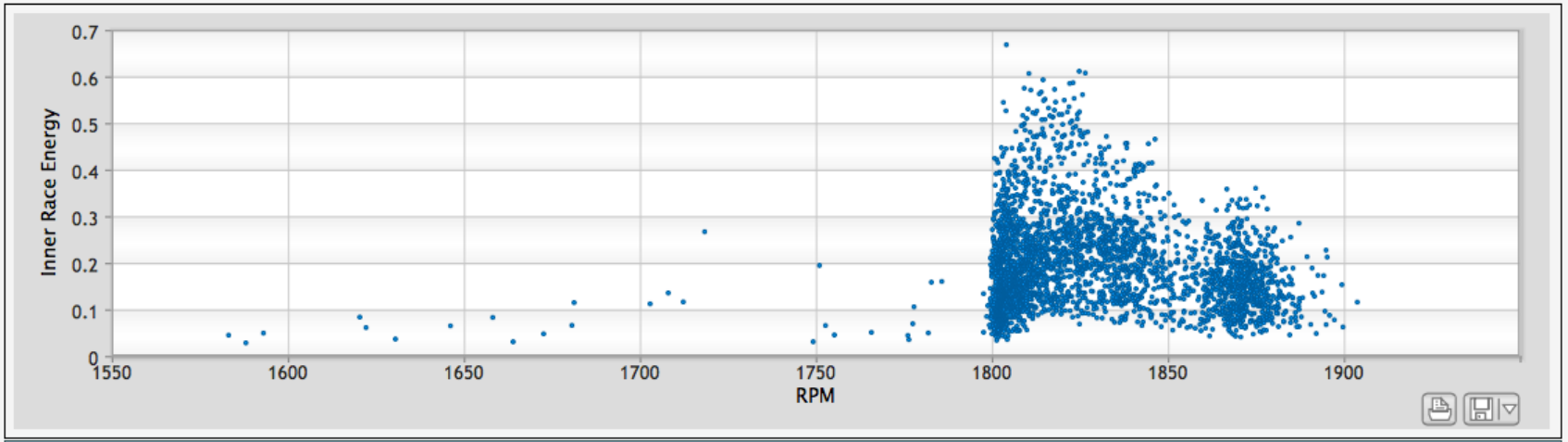
▼ CI Correlation

CI View: Determine Vault Type

Inner Race Vault
Ball, Cage and
Outer Race Starting
to Propagate



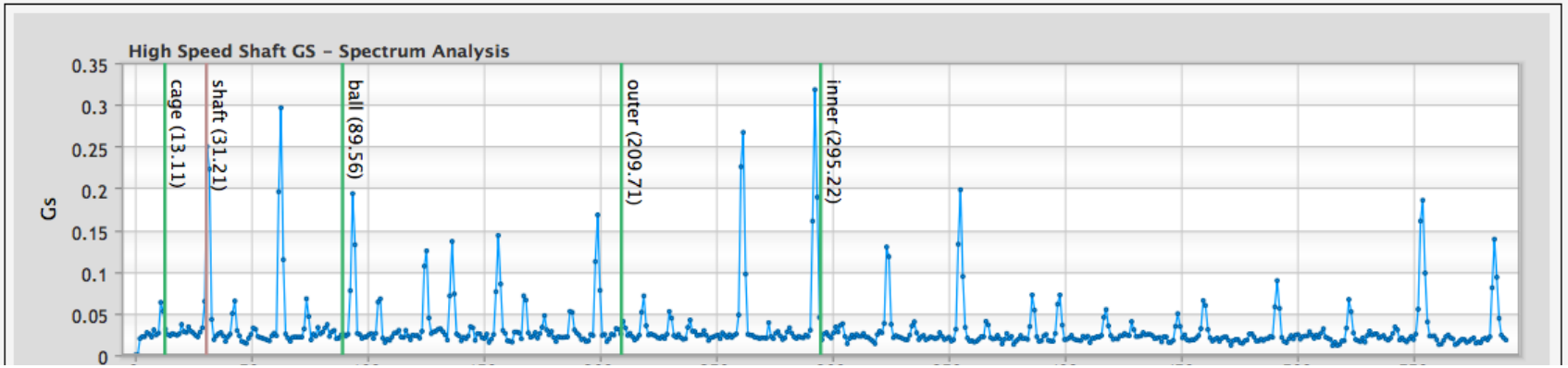
Engineering Analysis



Parameter Correlation

Component Detail

Select Detail Acquisition | Max Timestamp : 4/30/2013 | Update

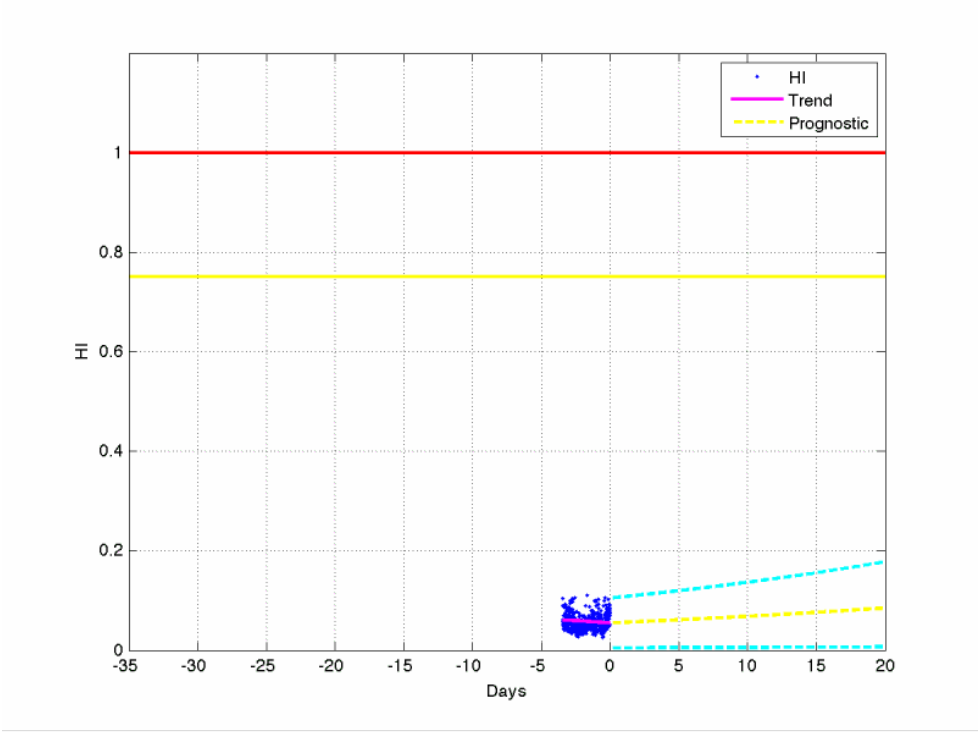


Prognostics

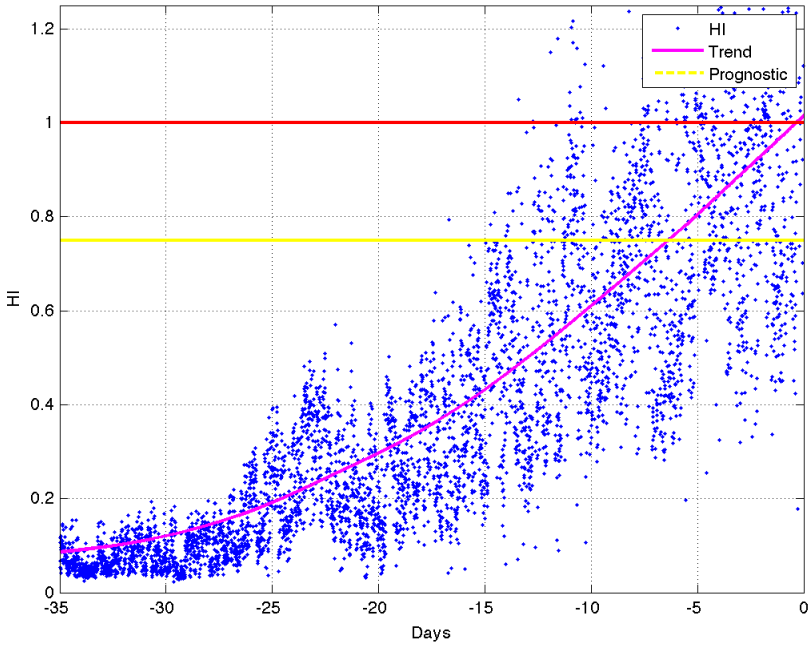
- Detection vs. Diagnostic vs. Prognostics
- Detection:
  - Its Broken
- Diagnostics:
  - What's Broken
- Prognostics:
  - When Its Going to be Broken
  - Logistic Support
  - Fleet Management
  - Opportunistic Maintenance
- Set Maintenance Policy:
  - Do Maintenance When HI is 1
  - Component is No Longer Good
- Remaining Useful Life (RUL) is the Time from the Current State Until HI >= 1
- Easy, If You Have a Fault Model

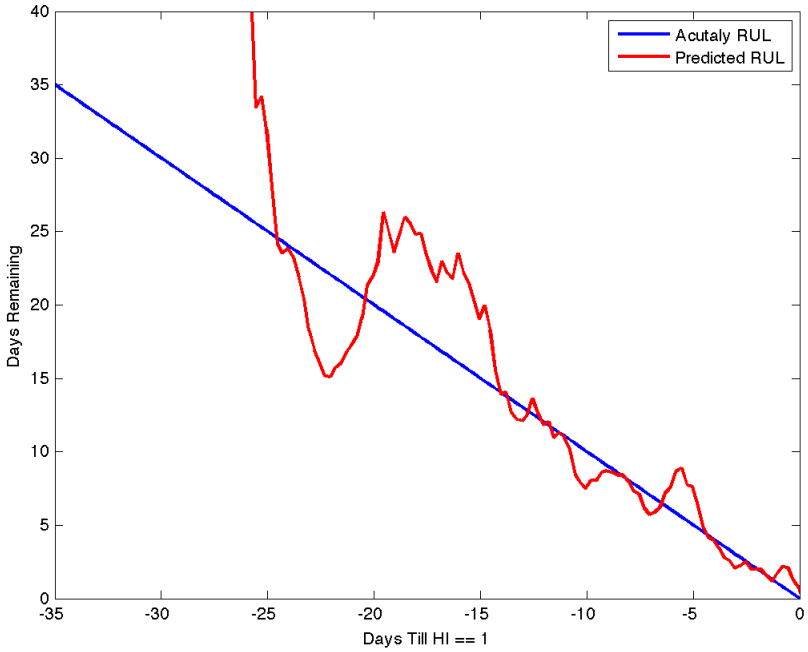
Real World Data Driven Prognostics

- High Speed Bearing
- Inner Race Fault
  - Cracked Race
  - At HI 1,
    - Cage, Ball, Outer Race Energy Started To Elevate



How Well Did We Do?





Fault Starts to Prorogate @-25 Days, Can See RUL Drop:
Fault Sensitive to Load: Only Had RPM
Used Nominal Power Output For RUL
RUL Based on Operational Hours: Wind Does not Blow All of the time
Calendar time? About x2, about 50 days

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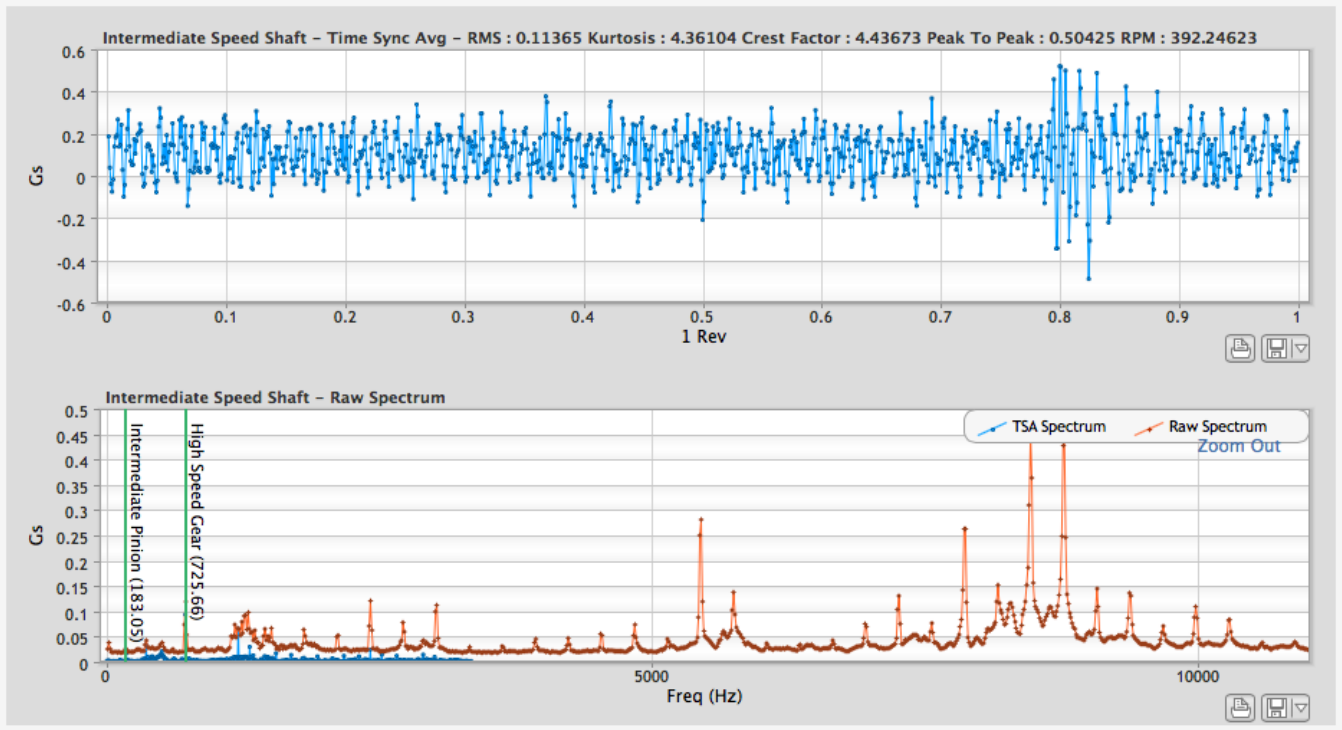
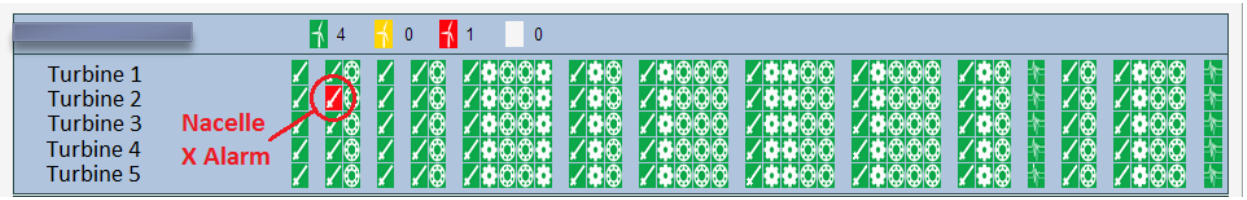
Engineering View:
Nice Gear Fault, Planet Fault

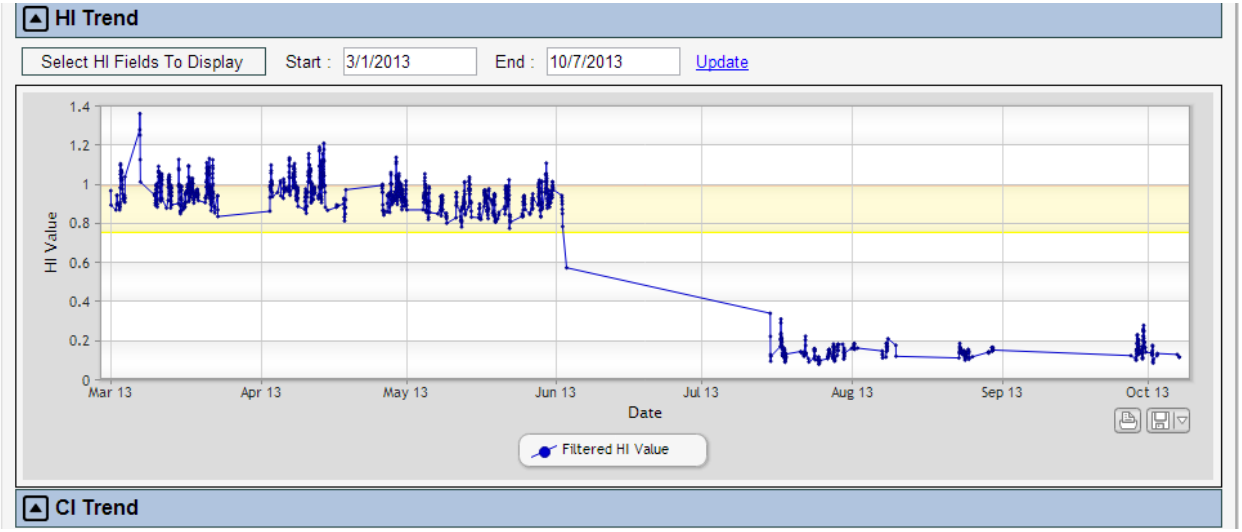
Waiting on
Bore scope



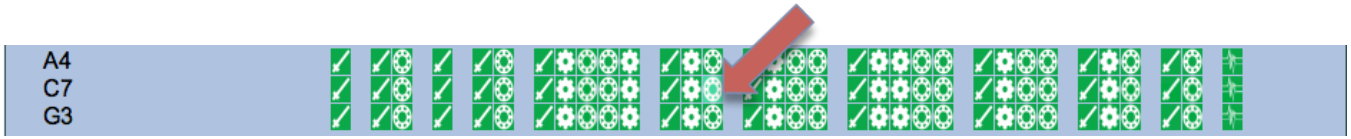
Low Frequency Sensitivity: Blade Balance, Icing Detection



True DC Measurement Capability
Blade Balance on Main Rotor: 0.11 Hz, 1.7 Isp (0.007 Gs)



Planet Fault

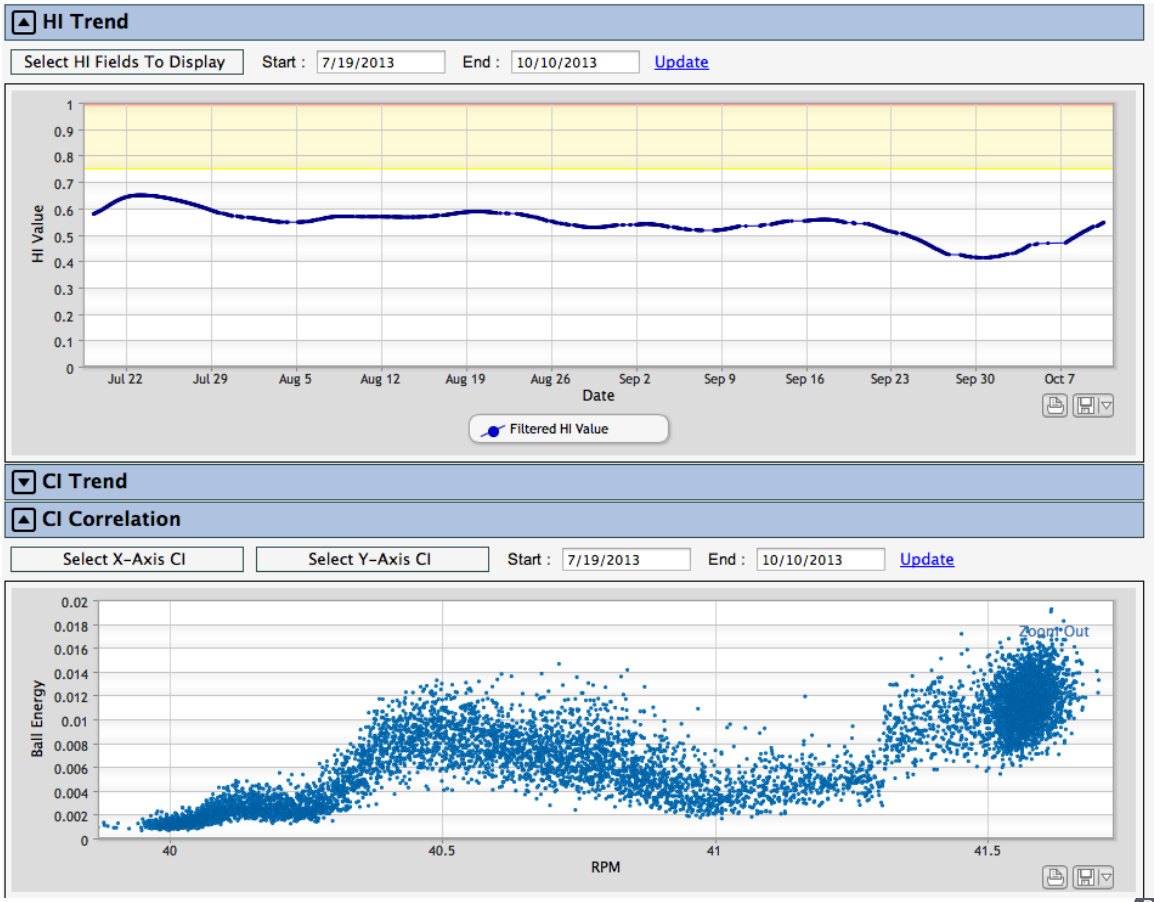


Elevated HI
> 0.5

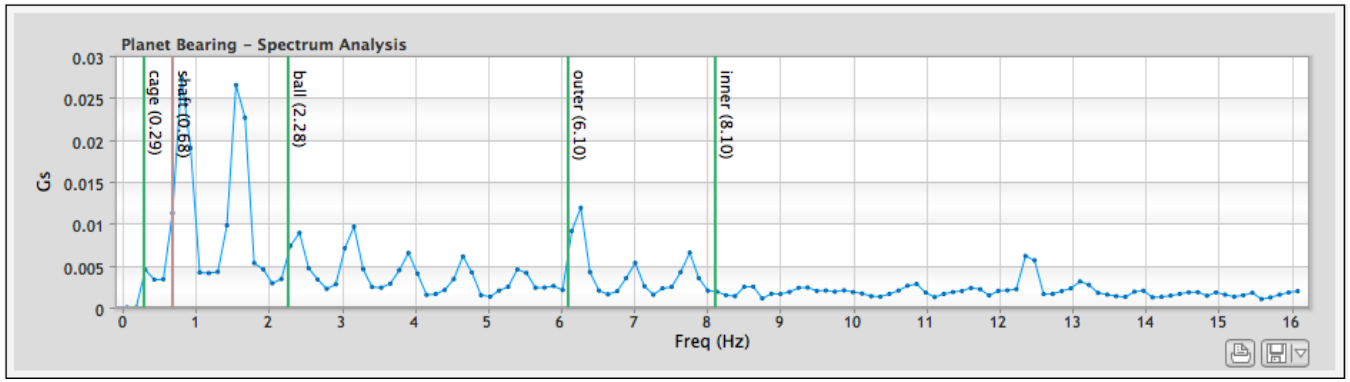
Explored Why There is Variation in the HI vs. Time

CI Correlation Shows Relationship Between CI/HI and RPM

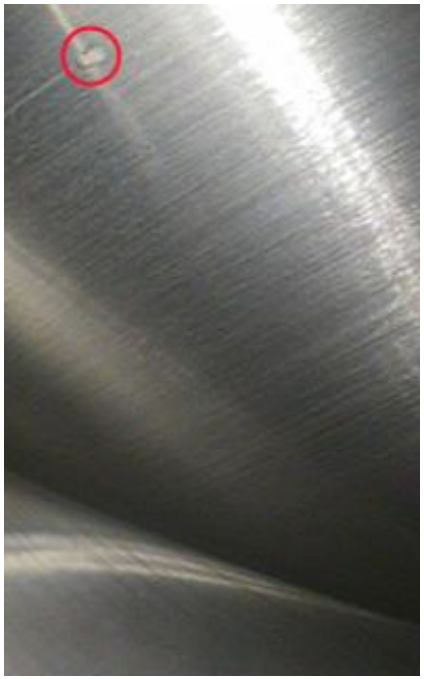
Should Change the Acquisition Window



Planet Fault



Why the Elevated CI?
Engineering View Show Outer Race Fault/Ball Fault
Subsequent Bore scope Confirmed



Goal: Improved CBM

- Lower the Cost of Projects by
  - Improving the Value of CBM
  - Simplified User Interface
  - No Monitoring Fee
  - Best In Class Analysis
    - Time Synchronous Averaging
      - Gear/Shaft
    - Resampling Algorithm for Bearing
  - 0-32 KHz Bandwidth Sensor (MEMS Accel)
  - True Prognostics Capabilty

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