Prognostics for Condition Based Maintenance

From monitoring and predictive diagnostics to state-of-the-art prognostics
The Cassantec management team

Moritz von Plate, CEO

- Agricultural Engineer, University of Bonn
- MBA, Georgetown University
- Seven years with The Boston Consulting Group in Berlin and Warsaw
- 2008–2012 CFO of Solarlite GmbH, an award-winning pioneer in solar-thermal power generation, Europe’s fastest growing cleantech company
- Since 03/2013 CEO of Cassantec AG

Dr. Frank Kirschnick, CTO

- Computer Scientist, Technical University of Munich
- MSc, PhD, Stanford University
- Two years at Siemens Corporate R&D, focusing on optimization of industrial assets through Artificial Intelligence and “Big Data Analytics”
- Five years with Arthur D. Little, three years as project manager
- In 2007 launched Cassantec AG, founding CEO
- Since 03/2013 CTO
The problem – (unplanned) downtime and operational inefficiency of industrial assets and the associated cost to avoid these issues through maintenance

Example: feedwater pump

✔ Pump is running

✖ Pump is down
Sensing equipment and real-time data analysis help prevent immediate threats – true condition based maintenance requires diagnostics and prognostics.

**Monitoring**
- Vibration, ultrasonic, infrared etc. sensors & devices
- Software for data illustration, mapping, projection, trending
- Lubricant, varnish and filter debris lab services

**Alert / Alarm** for immediate response

100+ Vendors

Different Complementary Approaches
The data gathered for monitoring are the basis for condition **diagnostics**. 

**Step 1** towards condition based maintenance – **prognostics still missing**

### Monitoring

- Vibration, ultrasonic, infrared etc. sensors & devices
- Software for data illustration, mapping, projection, trending
- Lubricant, varnish and filter debris lab services

### Diagnostics

- Advanced software based on equipment-specific models
- Specialized consultants, field technicians interpreting results
- Experts making predictions («predictive» diagnostics)

#### Different Complementary Approaches

<table>
<thead>
<tr>
<th>100+ Vendors</th>
<th>10+ Vendors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert / Alarm for immediate response</td>
<td>Insight for work orders</td>
</tr>
</tbody>
</table>
### Different Complementary Approaches

**Same data used for **prognostics**

**Step 2 towards condition based maintenance – prognostics by Cassantec**

<table>
<thead>
<tr>
<th>Monitoring</th>
<th>Diagnostics</th>
<th>Prognostics</th>
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<td>▶ Experts making predictions («predictive» diagnostics)</td>
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**Insight**

- **Vibration, ultrasonic, infrared etc. sensors & devices**
- **Software for data illustration, mapping, projection, trending**
- **Lubricant, varnish and filter debris lab services**

**Foresight**

- **Objective, condition-based info on remaining useful life (RUL)**
- **Computed risk profiles over a significant, future time horizon**
- **Online solution utilizing data and functions already available**
Cassantec’s **prognostic** solution and competition’s **diagnostic** solutions complement each other, addressing very different questions.

- **What** is the condition of our power plant?
- **Why** is this condition critical, or why not?
- **Which** parameters are most indicative?
- **Where** do we find problem root causes?
- **How** do we best resolve challenges?

- **When** will this condition become critical?
- **When** will we get a warning, alert or alarm?
- **When** will be the best time to fix problems?
- **Will** we make it until the next scheduled outage?
- **Will** other plants in the fleet have the same issue?
Our online solution summarizes diagnostic insight, presents prognostic foresight and supports decisions regarding long-term asset management.
We **integrate** and **consolidate** current and historical condition and process data available to the operator through a proprietary computational model.
The accuracy of our solution has been confirmed via retrospective analysis – this accuracy increases over time through machine learning.

- In retrospect, 99% of predictable malfunctions were accurately predicted, with a horizon of up to 5 years (!)
- Operator knowledge was exceeded by 20%, with several surprises (e.g. cartridge sealing, which the operator assumed Cassantec would not find – analysis result on next page)
- Diagnostics und prognostics are enhanced over time through machine learning
The pressure differences between different pump stages allow projection of washed out cartridge sealing (and steel casing) several years ahead.

Prognostic Report for Feed Water Pumps

Post-mortem Example

Prognostic Accuracy

6 years
Data diagnostics help localize problems, but are not capable of forecasting these – example of 2 unanticipated downtime events

<table>
<thead>
<tr>
<th>Unit</th>
<th>Steam Generator Defects</th>
<th>Downtime Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace</td>
<td>Forced draft fan</td>
<td></td>
</tr>
<tr>
<td>Superheater</td>
<td>Induced draft fan</td>
<td></td>
</tr>
<tr>
<td>Reheater</td>
<td>Steam drum</td>
<td></td>
</tr>
<tr>
<td>Economizer</td>
<td>Main steam line</td>
<td></td>
</tr>
<tr>
<td>Firing system</td>
<td>Water wall drum</td>
<td></td>
</tr>
<tr>
<td>Air heater</td>
<td>Ash pit</td>
<td></td>
</tr>
</tbody>
</table>
Observation: Available data allow to forecast (not just diagnose) such events
Example: Recorded acoustic signals before trip (monitoring gave no warning)

<table>
<thead>
<tr>
<th>Steam Generator Data Sources</th>
<th>Data Source (1 of many)</th>
<th>Forecast Potential</th>
</tr>
</thead>
</table>

- Acoustic data
- Gas temperature
- Metal temperature
- Water chemistry
- Pressure data
- Fuel data

Mistras / Triple 5
Metalborne acoustic sensor

Forecast published
Observation: Available data allow to forecast with significant time horizon
Example: Recorded acoustic signals allow event forecast with 4 week horizon

Steam Generator Data Sources

Data Source (1 of many)

Forecast Potential

Mistras / Triple 5 metalborne acoustic sensor

A Acoustic data
B Gas temperature
M Metal temperature
W Water chemistry
P Pressure data
F Fuel data

Forecast published
While Cassantec offers the same benefits as its best competitors in the diagnostic segment, additional prognostic benefits yield a superior value.

**Same benefit as (best) competitor(s)**

- Data **consolidation**, **integration** and **storage** functions
- In-depth methodologically sound **diagnosis** function
- Targeted **insight** on safety flaws, inefficiencies, malfunctions and imminent failure
- Asset mgt. **decision support** function at different hierarchy levels
- **Robust** enough to compensate single data flaws and bad sensors
- **Quick** and **easy** to implement
- **Scalable** to handle large deployments
- Possibility to combine with 1\textsuperscript{st} and 2\textsuperscript{nd} level **technical support**
- Possibility to **host** solution **internally** or **externally**
- Single uniform and very **user-friendly interface**

**Additional, unique benefits**

- **Explicit prognostic horizon** allowing downtime minimization (beyond failure elimination)
  - Minimal unscheduled downtime via forecast flexibility
  - Minimal scheduled downtime via forecast preparation
- **Explicit risk profiles**
  - Allowing communication and backing of top-level decision makers
Several levers for financial improvements are made available through Cassantec’s prognostic reports

<table>
<thead>
<tr>
<th>Benefit lever</th>
<th>Applicable?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce unscheduled maintenance and/or repair</td>
<td>TBD</td>
<td>Are there unscheduled maintenance and repair costs that could be reduced through better foresight?</td>
</tr>
<tr>
<td>Shift maintenance into low-cost periods</td>
<td>TBD</td>
<td>Is it possible to use prognostic foresight to schedule maintenance when cost is expected to be low?</td>
</tr>
<tr>
<td>Shift maintenance into low-revenue periods</td>
<td>TBD</td>
<td>Is it possible to use foresight to schedule maintenance when revenue from production is expected to be low?</td>
</tr>
<tr>
<td>Reduced preventive scope and/or frequency</td>
<td>TBD</td>
<td>Does $\Delta$ risk justify $\Delta$ cost? (Cassantec computes $\Delta$ risk!)</td>
</tr>
<tr>
<td>Better maintenance work order preparation</td>
<td>TBD</td>
<td>Does Cassantec provide better foresight and/or diagnostics than current systems?</td>
</tr>
<tr>
<td>Preempt damages</td>
<td>TBD</td>
<td>Does Cassantec provide earlier warnings and/or better diagnostics than current systems?</td>
</tr>
<tr>
<td>Reduce redundancies</td>
<td>TBD</td>
<td>Does $\Delta$ risk justify $\Delta$ cost? (Cassantec computes $\Delta$ risk!)</td>
</tr>
<tr>
<td>Enhance reputation</td>
<td>TBD</td>
<td>Secured position as a quality, reliability and/or availability leader</td>
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</table>
Reducing 17 unplanned outages to 6 using Cassantec’s prognostics on the available acoustic data

Prognostic Report for Steam Boiler

- M1 - Ash (sand) erosion at lower furnace exit (lower slope area)
- M2 - Ash (sand) erosion at reheater tube
- M3 - Steam blower erosion at support tube
- M4 - Steam blower erosion at superheater tube
- M5 - Thermal shock (excessive use of water cannon) at primary furnace
- M6 - Ash bridging (overpiling) at lower slope area
The solution can be provided on an ongoing basis, e.g. through a web-based service – pump example

- Automated condition data sourcing, transfer, evaluation and reporting
- Data pulled from PI system through a port in the firewall
- Shifting focus from data management to reliability and asset management

The solution can be provided on an ongoing basis, e.g. through a web-based service – pump example

- Sample Evaluation
- Sample Rating
- Data Reporting

Automated condition data sourcing, transfer, evaluation and reporting

Data pulled from PI system through a port in the firewall

Shifting focus from data management to reliability and asset management
The configuration process absorbs very limited capacity on the customer side and takes only a few weeks.

1. Prioritize & Discuss Data
   - Specify/prioritize equipment
   - Discuss condition data
     - Types
     - Sources
     - Intervals
   - Provide historical condition data
     - Specify
     - Hand-over
     - Review

2. Specify Malfunction Modes
   - Specify malfunction modes
     - Definition
     - Detection
     - Response
   - Prioritize malfunction modes
   - Correlate condition parameters to malfunction modes
     - Qualitative
     - Quantitative

3. Configure Solution
   - Configure front end
     - Equipm. view
     - Unit view
     - Fleet view
   - Customize comput. model
   - Discuss results
     - Specification & assumptions
     - Data time series
     - Implications for asset mgt.

4. Automate Data Transfer
   - Batch Specification
     - Data sources
     - Data format
     - Time intervals
   - Configuration and tests

5. Use Forecasts
   - Unit level:
     - Consideration of forecasts in
       - Scheduling
       - Scoping
       - Preparation of outages
     - Consideration of forecasts in life cycle and retrofit decisions
   - Fleet level:
     - Consideration of forecasts in commercial decisions

Cassantec - internal
1 day IT
Ongoing use

1/2 day onsite
2 days onsite

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We suggest to conduct a demonstration project for first-hand experience

Applicable for rotating and non-rotating equipment

- **No surprises**: Recognize problems earliest, avoid unscheduled outages
- **No lost lifetime**: See if maintenance can wait until next scheduled outage
- **No guesswork**: Know what/why/how to maintain during scheduled outage, eliminate gut feel decisions on future
- **No hassle**: more planning horizon, less fire fighting
- **No software**: full online service, not need for training
- **No time wasted**: full automation, integration, reporting
### Is Prognostics already part of your routine?

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
<tr>
<td><strong>1.</strong> Do you incorporate the future equipment condition into your maintenance decisions?</td>
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<tr>
<td>Relevant is the future condition of an individual component rather than the current condition or fleet / industry averages.</td>
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<tr>
<td><strong>2.</strong> Do your forecasts work with explicit time horizons and probabilities?</td>
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<tr>
<td>E.g.: “Malfunction X has a Y% probability of occurring on date xx.xx.xxxx and a Z% probability of occurring on date xx.xx.xxxx.” versus “A data anomaly indicates that malfunction X will probably occur within the next days to weeks, possibly months.”</td>
<td></td>
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<tr>
<td><strong>3.</strong> Do you use forecasts across all critical assets?</td>
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<tr>
<td>Is the prognosis provided by one coherent and comprehensive solution rather than having different solutions for different assets and none for some critical assets?</td>
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<tr>
<td><strong>4.</strong> Do you utilize all types of available data for forecasting?</td>
<td></td>
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<tr>
<td>Is the prognosis based on all available process (e.g. temperature, pressure, flow, speed, current) and condition (e.g. vibration, lubricant analysis, acoustics) data rather than using only one set of data (e.g. only motor current)?</td>
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# Prognostics Readiness – why it is never too early to start

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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you gather <strong>process data</strong> and <strong>condition data</strong> on your critical equipment?</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td>If “Yes” to both:</td>
<td><strong>You are ready for Prognostics!</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Do you keep <strong>data histories</strong>, e.g. in a historian?</td>
<td>Yes</td>
<td>No</td>
<td></td>
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</table>

**Benefits from starting early**

- **You prognosticate already** – by operating equipment and planning future maintenance interventions. Why not get decision support from your data?
- **Get support in planning your road ahead** – which data upgrades are needed where?
- **Focus your efforts** – where are gaps in understanding assets? Which assets are most critical? Where to focus maintenance efforts?
- **Free up time of your engineers** – reduce the time spent on sifting through raw data, increase the time spent solving impending issues
- **Cross-organizational learning and benchmarking** – create transparency and learning opportunities
- **Top management decision support** – use easy-to-interpret Prognostic Reports to facilitate top level decision making
- **No risk, limited cost** – full online service (SaaS), no need for training
### Prognostics – the differentiation

<table>
<thead>
<tr>
<th>Versus</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Condition monitoring</strong></td>
<td>We relate the condition data to the current and future malfunction risks whereas condition monitoring software is based on data projections, illustrations, and comparisons to generic alarm levels.</td>
</tr>
<tr>
<td><strong>Diagnostics and Predictive Analytics</strong></td>
<td>We answer the questions related to timing (when) whereas Diagnostics and Predictive Analytics focus on answering questions on the current equipment condition (what / why / where).</td>
</tr>
<tr>
<td><strong>ERP and asset management</strong></td>
<td>We provide decision support based on the current and future asset conditions and malfunction risks whereas ERP and asset management software offer limited top-level statistics.</td>
</tr>
<tr>
<td><strong>work order management</strong></td>
<td>We help prioritize and select work orders based on malfunction risks for critical assets. This, in turn, may be important input for work order management.</td>
</tr>
</tbody>
</table>
**Diagnostics vs. Prognostics**

**Diagnostics**
- **What** is the equipment condition?
- **Why** is this condition critical, or why not?
- **Which** data parameters are most indicative?
- **Where** are the problem’s root causes?
- **How** do we best resolve challenges?

**Prognostics**
- **When** will this condition become critical?
- **When** will we get a warning, alert or alarm?
- **When** will be the best time to fix problems?
- **Will** we make it until the next scheduled outage?
- **Will** other plants in the fleet have the same issue?
Cassantec is an independent provider of **integrated, automated prognostic solutions** for critical power plant assets with a unique, protected technology

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<th><strong>Briefing on Cassantec AG</strong></th>
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<td><strong>Meaning:</strong> Cassantec = <strong>Cassandra Technologies</strong></td>
</tr>
<tr>
<td><strong>Launch:</strong> Latest platform launched in 2007, U.S. market entered in 2009</td>
</tr>
<tr>
<td><strong>Locations:</strong> HQ in <strong>Zurich</strong>, branches in <strong>Berlin</strong> and <strong>Cleveland</strong>, Ohio</td>
</tr>
<tr>
<td><strong>Position:</strong> Independent provider of automated, high-end <strong>prognostic solutions</strong> for industrial asset management</td>
</tr>
<tr>
<td><strong>Technology:</strong> Novel combination of mathematical <strong>best practice</strong> techniques backed by proprietary <strong>reference database</strong> from industry partner</td>
</tr>
<tr>
<td><strong>Offering:</strong> <strong>Prognostic reports</strong> and <strong>availability forecasts</strong> with periodical updates (subscription) for industrial equipment operators</td>
</tr>
<tr>
<td><strong>References:</strong> <strong>Chemical, Power, Transportation, Upstream Oil &amp; Gas</strong> (USA and Europe)</td>
</tr>
<tr>
<td><strong>Promoters:</strong> Swiss government (CTI Label), opinion leaders</td>
</tr>
<tr>
<td><strong>Industry Partner:</strong> Collaboration with leading U.S. lubricant lab (<strong>Insight Services</strong>) and leading acoustic sensor provider (<strong>Triple 5</strong>)</td>
</tr>
<tr>
<td><strong>Academic Partner:</strong> EPFL, Stanford University</td>
</tr>
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*Cassandra* prophet of critical future events in Greek mythology
Please contact us!

Team

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