Prognostics for Condition Based Maintenance

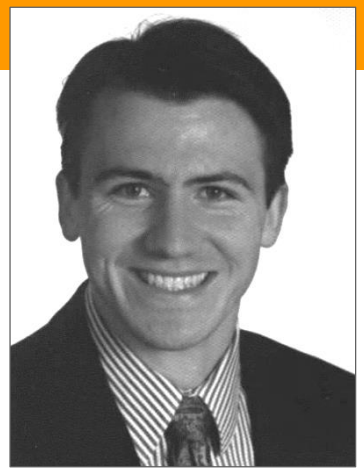
From monitoring and predictive diagnostics to state-of-the-art prognostics

CASSANTEC

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

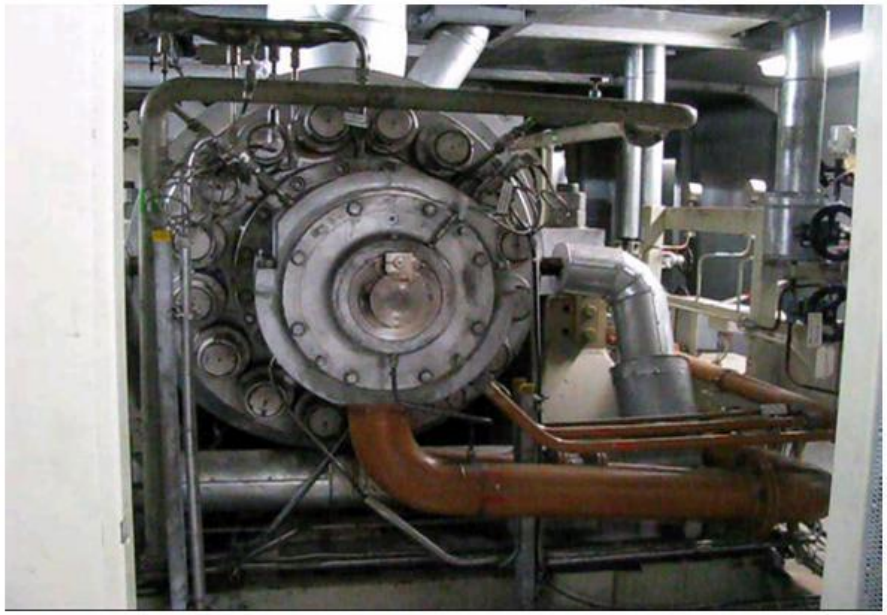
- Computer Scientist, Technical University of Munich
- MSc, PhD, Stanford University
- Two years at Siemens Corporate R&D, focusing on optimization of industrial assets through Artificial Intelligence and "Big Data Analytics"
- Five years with Arthur D. Little, three years as project manager
- In 2007 launched Cassantec AG, founding CEO
- Since 03/2013 CTO

1 Introduction of Cassantec

2 Summary

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

100+ Vendors

- 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

The data gathered for monitoring are the basis for condition diagnostics
Step 1 towards condition based maintenance – prognostics still missing

Monitoring	Diagnostics
100+ Vendors	10+ Vendors
▶ Vibration, ultrasonic, infrared etc. sensors & devices ▶ Software for data illustration, mapping, projection, trending ▶ Lubricant, varnish and filter debris lab services	▶ Advanced software based on equipment-specific models ▶ Specialized consultants, field technicians interpreting results ▶ Experts making predictions («predictive» diagnostics)
Alert / Alarm for immediate response	**Insight** for work orders

GE Intelligent Platforms
DALOG Diagnosesysteme GmbH
bpl GLOBAL A QUALITROL Company
EtaPRO™
PROGNOST Intelligence on Duty
Osys Part of the Rolls-Royce Group
INSTEP
CURTISS WRIGHT Flow Control Company
SCIENTECH

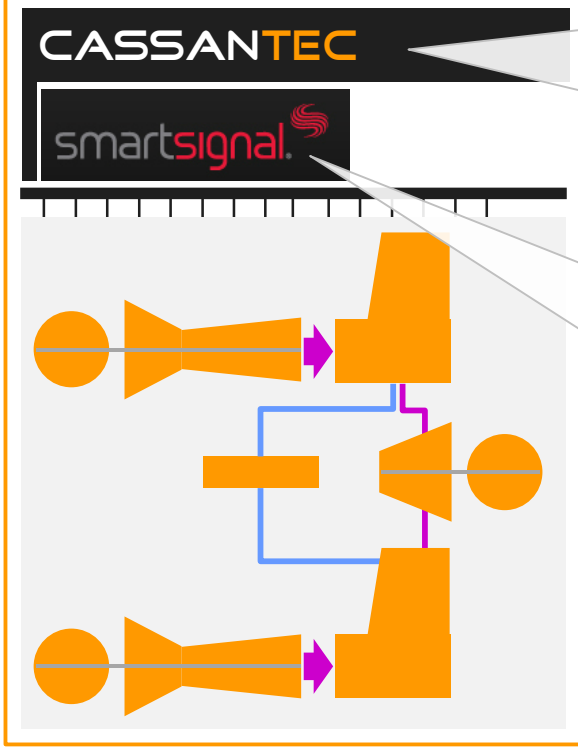
Same data used for prognostics
Step 2 towards condition based maintenance – prognostics by Cassantec

Monitoring	Diagnostics	Prognostics
100+ Vendors	10+ Vendors	CASSANTEC
▶ Vibration, ultrasonic, infrared etc. sensors & devices ▶ Software for data illustration, mapping, projection, trending ▶ Lubricant, varnish and filter debris lab services	▶ Advanced software based on equipment-specific models ▶ Specialized consultants, field technicians interpreting results ▶ Experts making predictions («predictive» diagnostics)	▶ 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
Alert / Alarm for immediate response	**Insight** for work orders	**Foresight** for long-term planning

Cassantec's prognostic solution and competition's diagnostic solutions complement each other, addressing very different questions

Power Plant Example

Combined Cycle Plant



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?

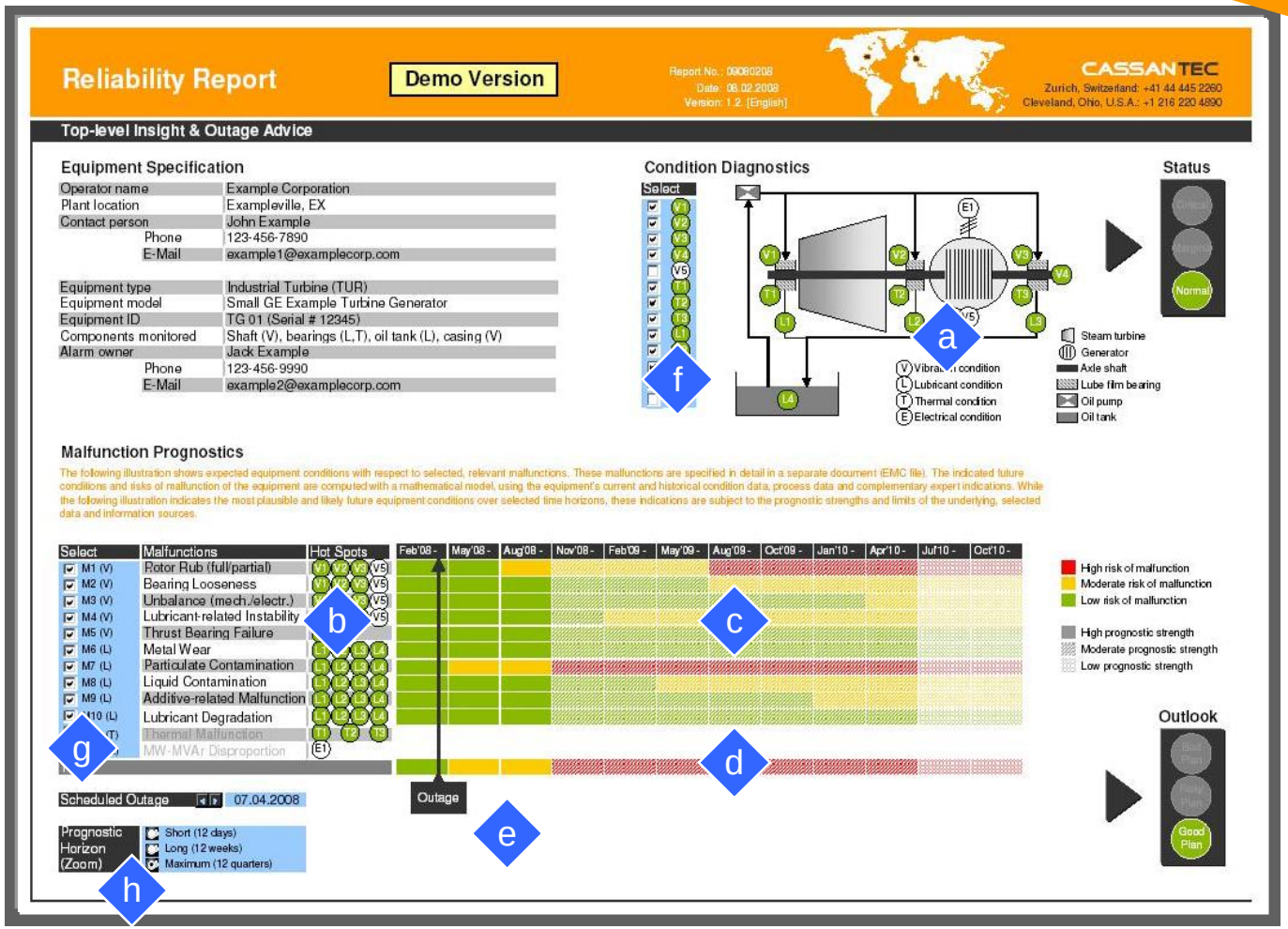
When / Will

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?

What / Why / Which / Where / How

Our online solution summarizes diagnostic insight, presents prognostic foresight and supports decisions regarding long-term asset management

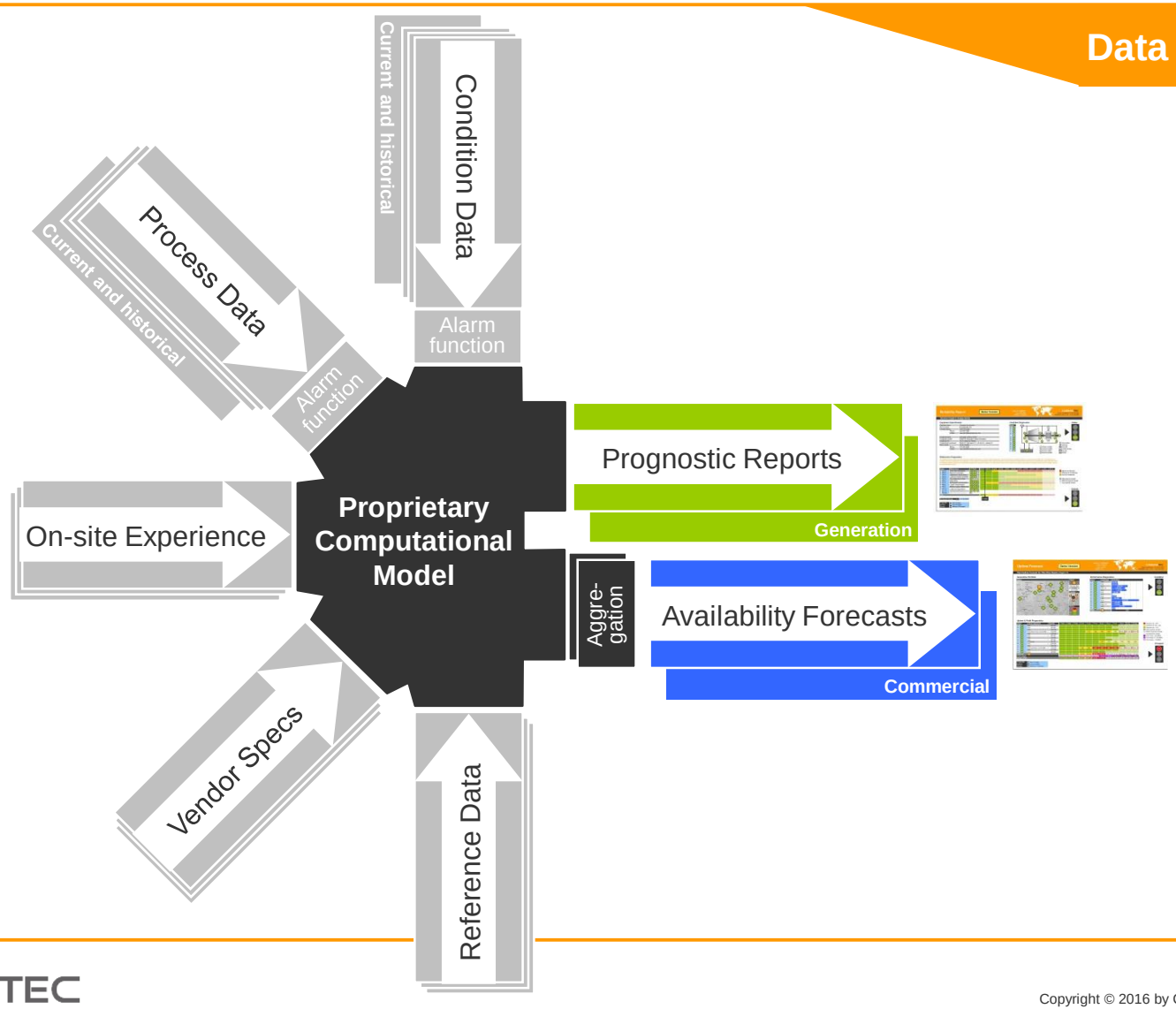
Prognostic Report



- a View condition diagnostics
- b View malfunction diagnostics
- c View malfunction prognostics
- d Aggregate prognostics
- e Cross-check maintenance plan
- f Extend condition data sources
- g Extend malfunction modes
- h Extend prognostic horizon

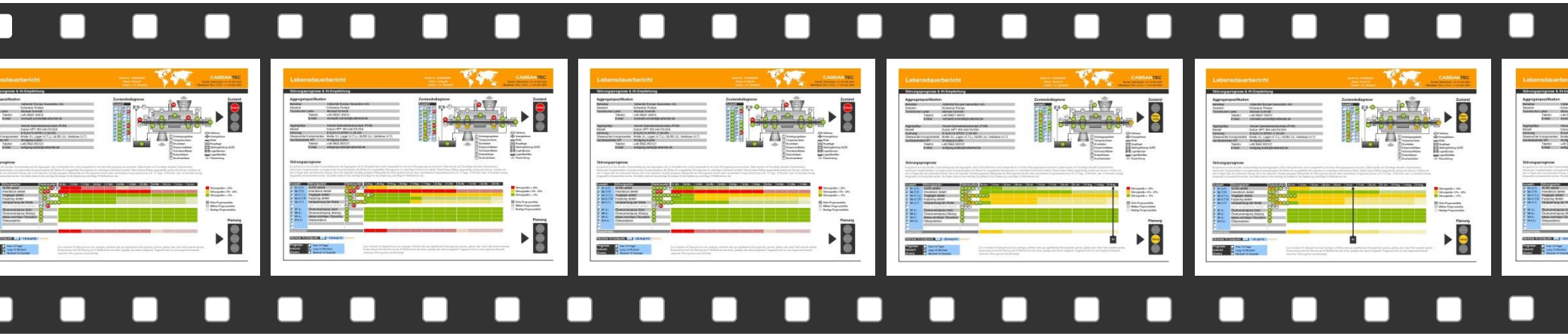
We integrate and consolidate current and historical condition and process data available to the operator through a proprietary computational model

Data Integration



The accuracy of our solution has been confirmed via retrospective analysis – this accuracy increases over time through machine learning

Retrospective Analysis



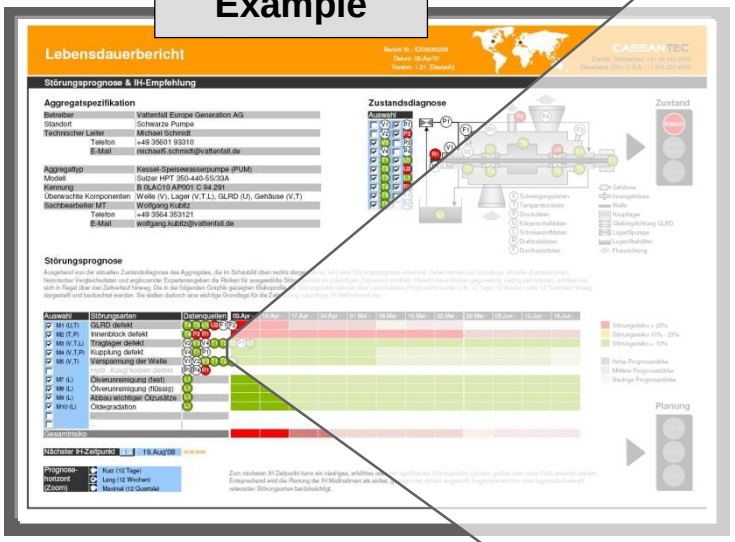
April 2007	August 2008	March 2009	June 2010	July 2010	No
Cartridge seals Mech. seals	Cartridge seals Mech. seals	Cartridge seals	Coupling Alignment	Coupling Alignment Mech. seal	OK

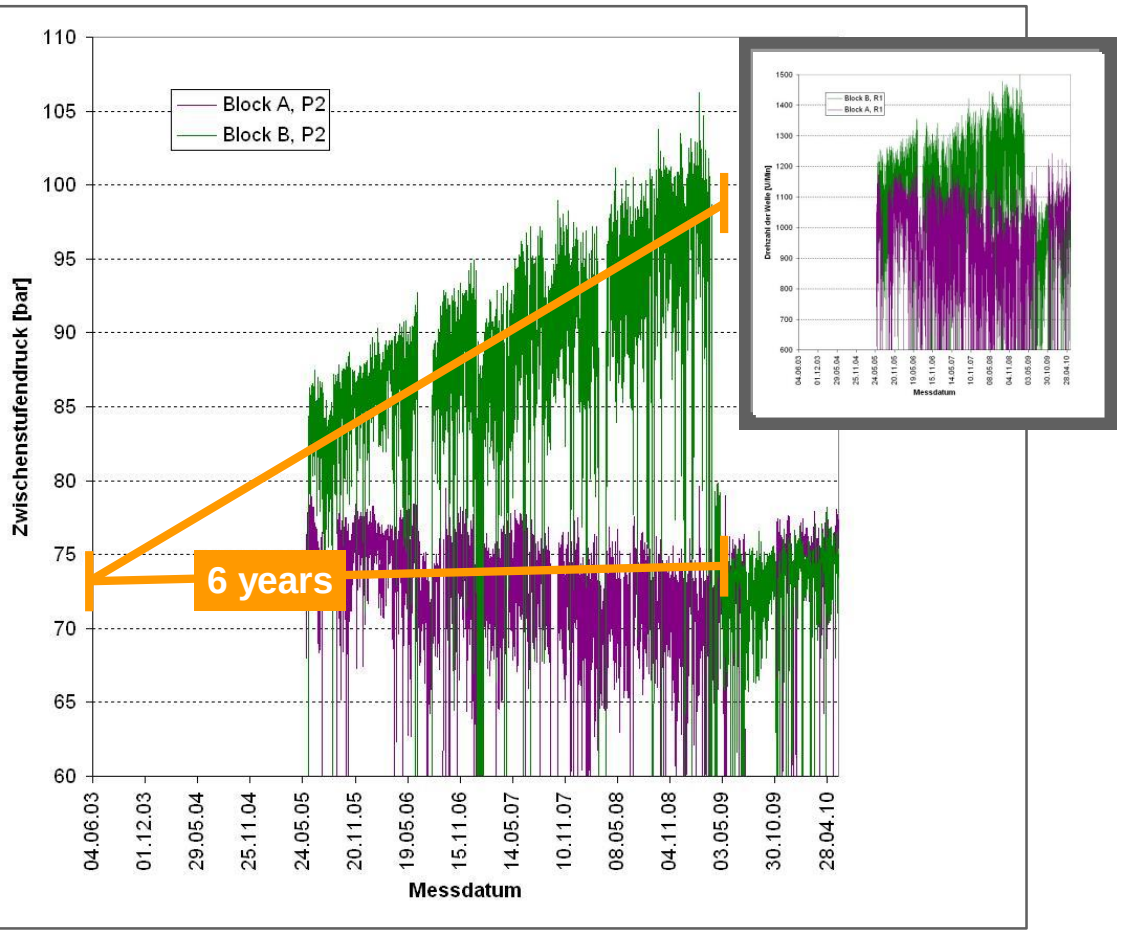
- In retrospect, 99% of predictable malfunctions were accurately predicted, with a horizon of up to 5 years (!)
- Operator knowledge was exceeded by 20%, with several surprises (e.g. cartridge sealing, which the operator assumed Cassantec would not find – analysis result on next page)
- Diagnostics und 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

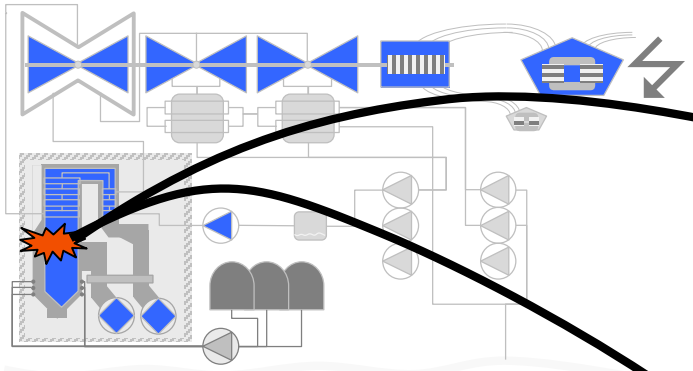
Post-mortem
Example

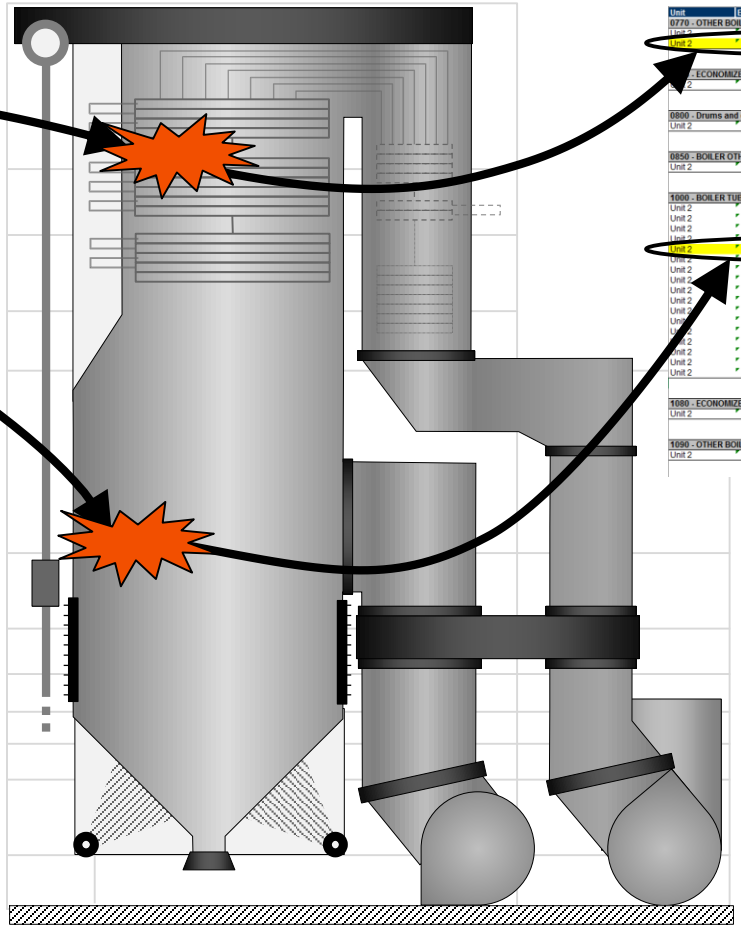


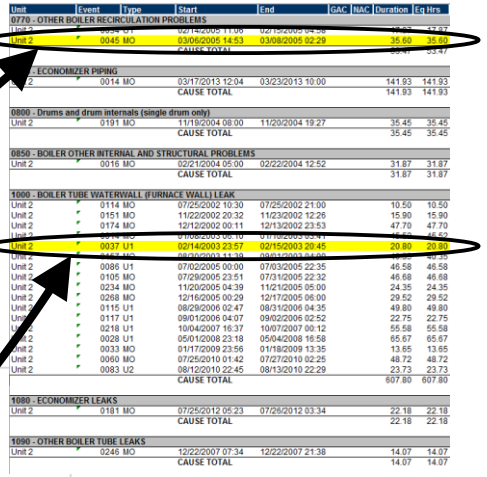


Data diagnostics help localize problems, but are not capable of forecasting these – example of 2 unanticipated downtime events

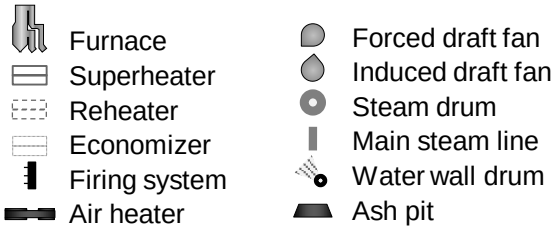
Unit	Steam Generator Defects	Downtime Statistics







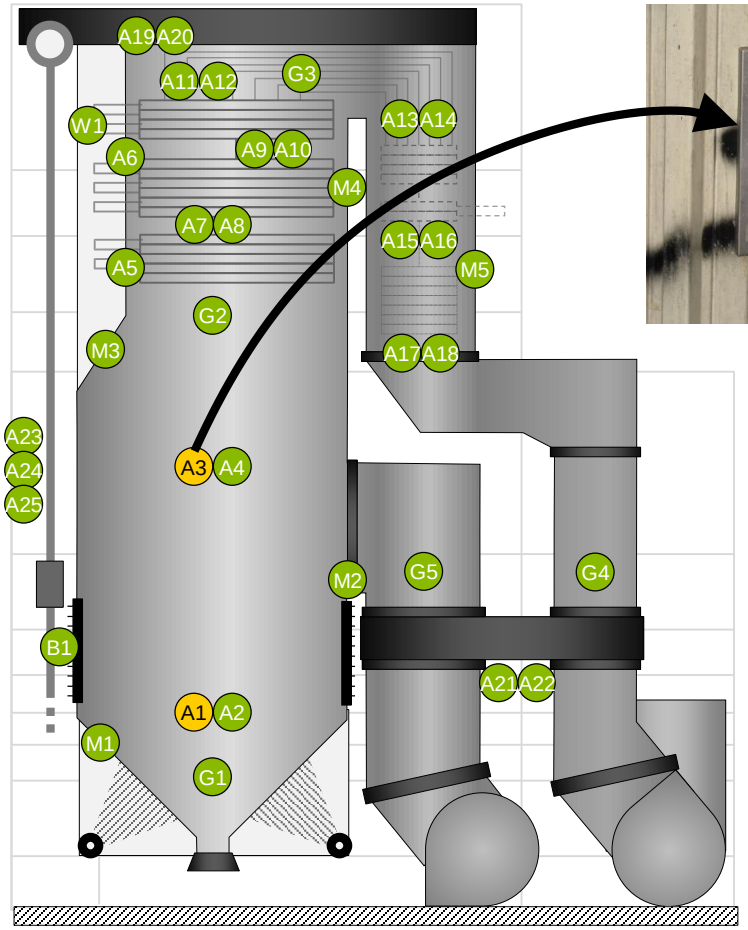
Unit	Event	Type	Start	End	GAC	NAC	Duration	Eq Hrs
0770 - OTHER BOILER RECIRCULATION PROBLEMS								
Unit 2	0045 MO		03/06/2005 14:53	03/08/2005 02:29			35.60	35.60
			CAUSE TOTAL				35.60	35.60
- ECONOMIZER PIPING								
Unit 2	0014 MO		03/17/2013 12:04	03/23/2013 10:00			141.93	141.93
			CAUSE TOTAL				141.93	141.93
0800 - Drums and drum internals (single drum only)								
Unit 2	0191 MO		11/19/2004 08:00	11/20/2004 19:27			35.45	35.45
			CAUSE TOTAL				35.45	35.45
0850 - BOILER OTHER INTERNAL AND STRUCTURAL PROBLEMS								
Unit 2	0016 MO		02/21/2004 05:00	02/22/2004 12:52			31.87	31.87
			CAUSE TOTAL				31.87	31.87
1000 - BOILER TUBE WATERWALL (FURNACE WALL) LEAK								
Unit 2	0114 MO		07/25/2002 10:30	07/25/2002 21:00			10.50	10.50
Unit 2	0151 MO		11/22/2002 20:32	11/23/2002 12:26			15.90	15.90
Unit 2	0174 MO		12/12/2002 00:11	12/13/2002 23:53			47.70	47.70
Unit 2	0037 U1		02/14/2003 23:57	02/15/2003 20:45			20.80	20.80
Unit 2	0086 U1		07/02/2005 00:00	07/03/2005 22:35			46.58	46.58
Unit 2	0105 MO		07/29/2005 23:51	07/31/2005 22:32			46.68	46.68
Unit 2	0234 MO		11/20/2005 04:39	11/21/2005 05:00			24.35	24.35
Unit 2	0268 MO		12/16/2005 00:29	12/17/2005 06:00			29.52	29.52
Unit 2	0115 U1		08/29/2006 02:47	08/31/2006 04:35			49.80	49.80
Unit 2	0117 U1		09/01/2006 04:07	09/02/2006 02:52			22.75	22.75
Unit 2	0218 U1		10/04/2007 16:37	10/07/2007 00:12			55.58	55.58
Unit 2	0028 U1		05/01/2008 23:18	05/04/2008 16:58			65.67	65.67
Unit 2	0033 MO		01/17/2009 23:56	01/18/2009 13:35			13.65	13.65
Unit 2	0060 MO		07/25/2010 01:42	07/27/2010 02:25			48.72	48.72
Unit 2	0083 U2		08/12/2010 22:45	08/13/2010 22:29			23.73	23.73
			CAUSE TOTAL				607.80	607.80
1080 - ECONOMIZER LEAKS								
Unit 2	0181 MO		07/25/2012 05:23	07/26/2012 03:34			22.18	22.18
			CAUSE TOTAL				22.18	22.18
1090 - OTHER BOILER TUBE LEAKS								
Unit 2	0246 MO		12/22/2007 07:34	12/22/2007 21:38			14.07	14.07
			CAUSE TOTAL				14.07	14.07



Observation: Available data allow to forecast (not just diagnose) such events

Example: Recorded acoustic signals before trip (monitoring gave no warning)

Steam Generator Data Sources	Data Source (1 of many)	Forecast Potential



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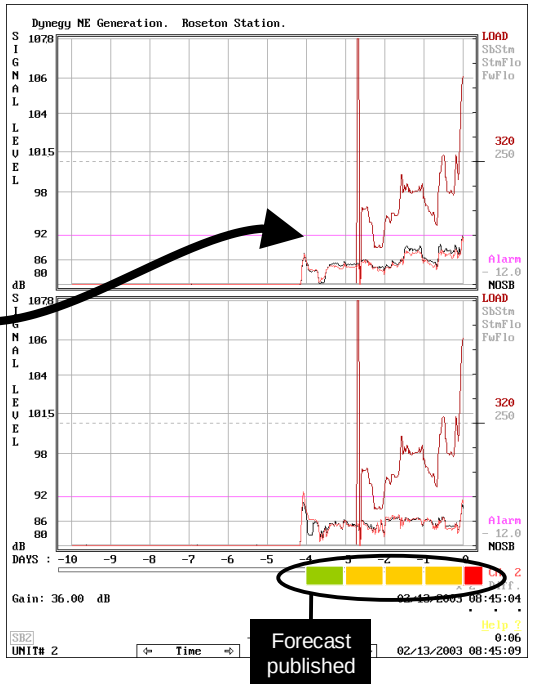

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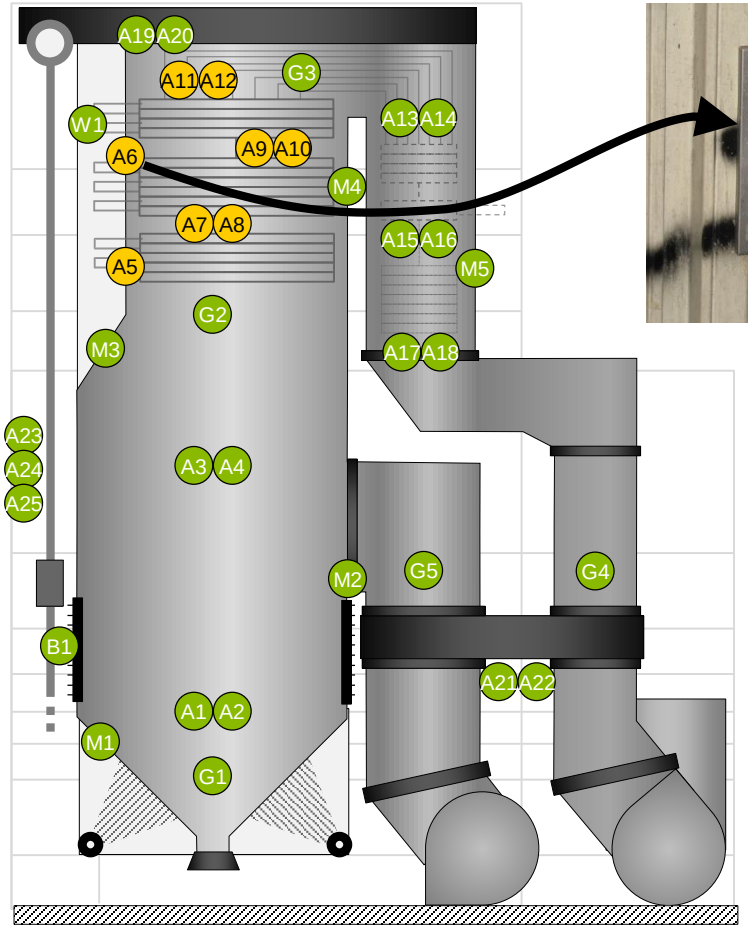
- (A) Acoustic data
- (G) Gas temperature
- (M) Metal temperature
- (W) Water chemistry
- (P) Pressure data
- (B) Fuel data

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



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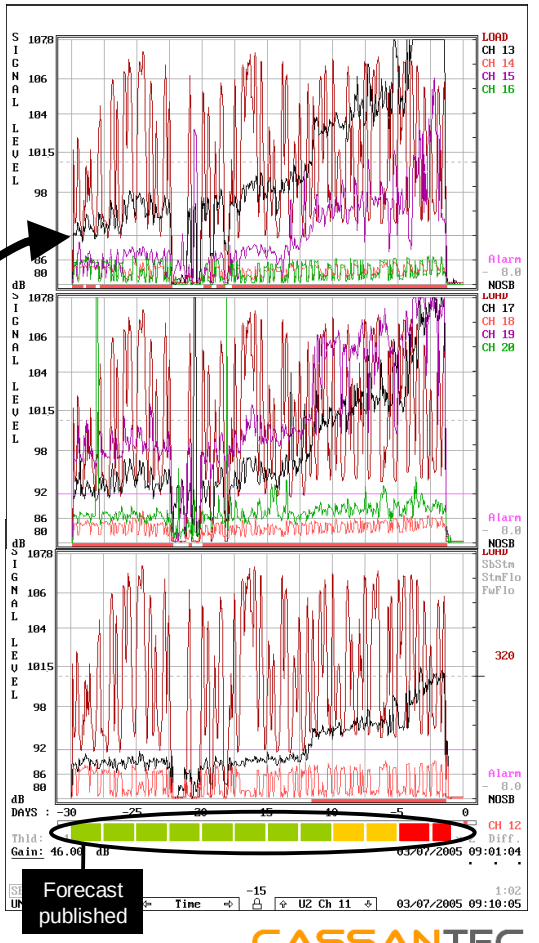


CASSANTEC

- (A) Acoustic data
- (G) Gas temperature
- (M) Metal temperature
- (W) Water chemistry
- (P) Pressure data
- (B) Fuel data

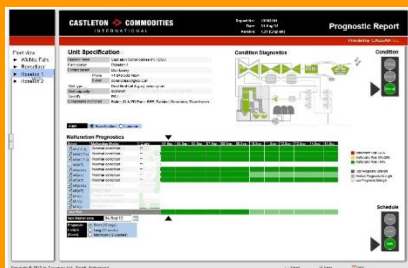
Solution Offering – Aggregated Level

Front end

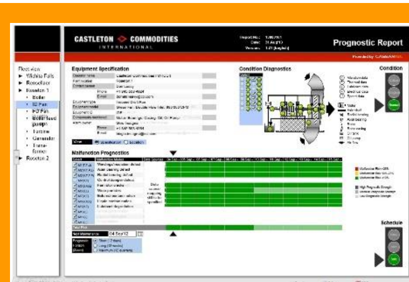
Login

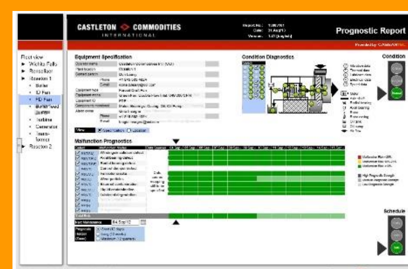
Fleet view

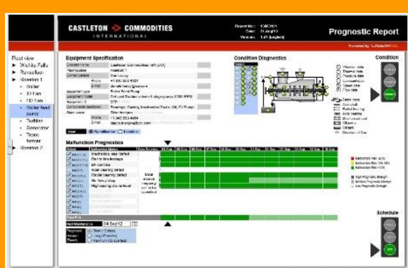
Unit view

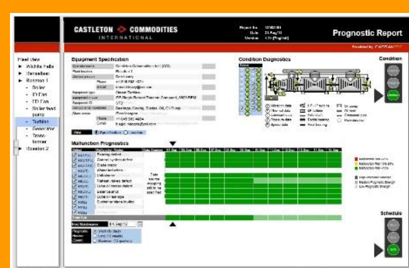


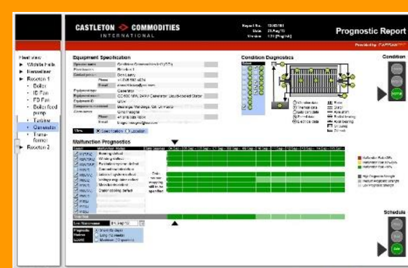
Component view











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 1st and 2nd level **technical support**
- Possibility to **host** solution **internally** or **externally**
- Single uniform and very **user-friendly interface**

Additional, unique benefits

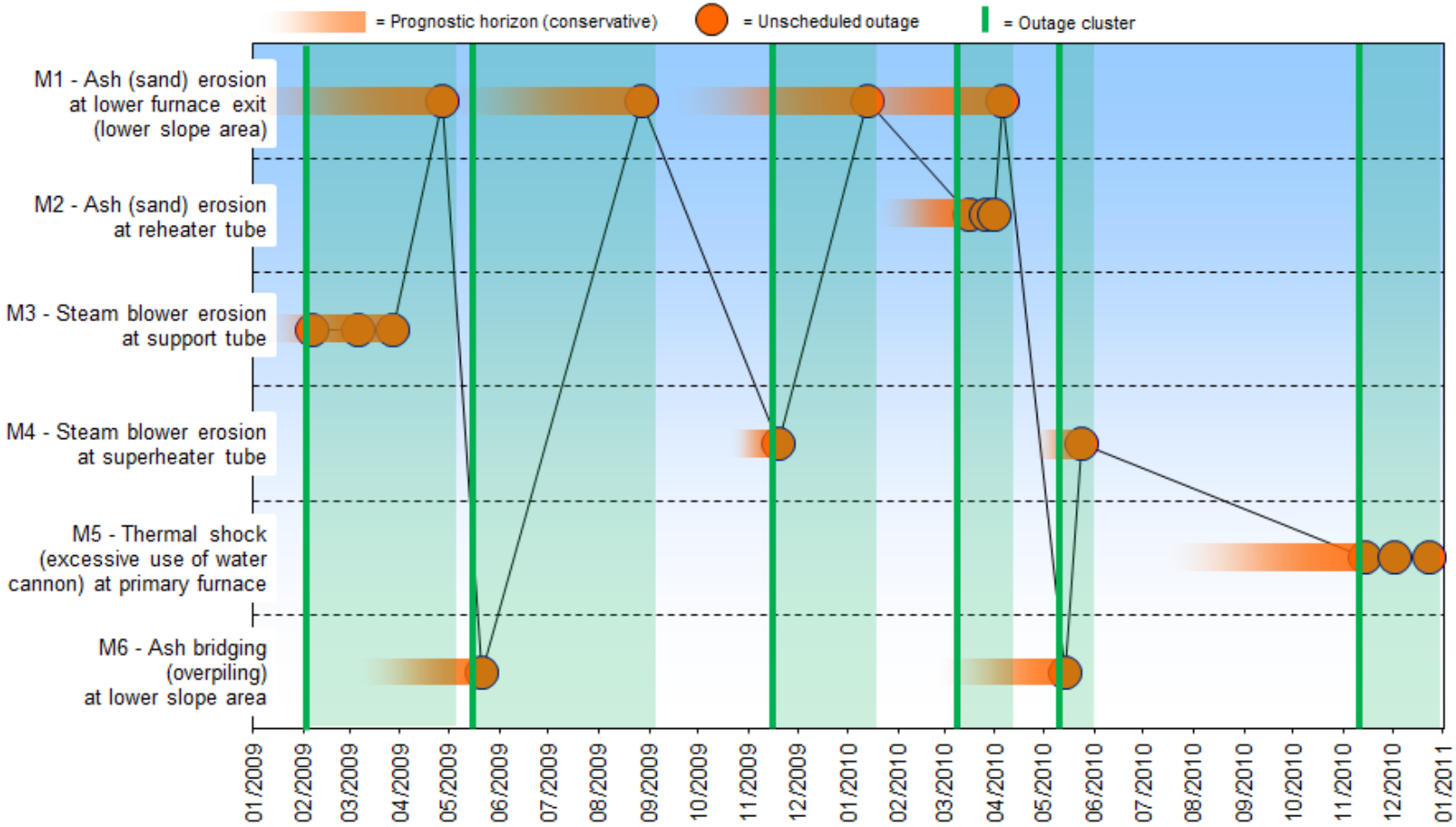
- Explicit **prognostic horizon** allowing downtime minimization (beyond failure elimination)
  - Minimal unscheduled downtime via forecast flexibility
  - Minimal scheduled downtime via forecast preparation
- Explicit **risk profiles**
  - Allowing communication and backing of top-level decision makers

Several levers for financial improvements are made available through Cassantec's prognostic reports

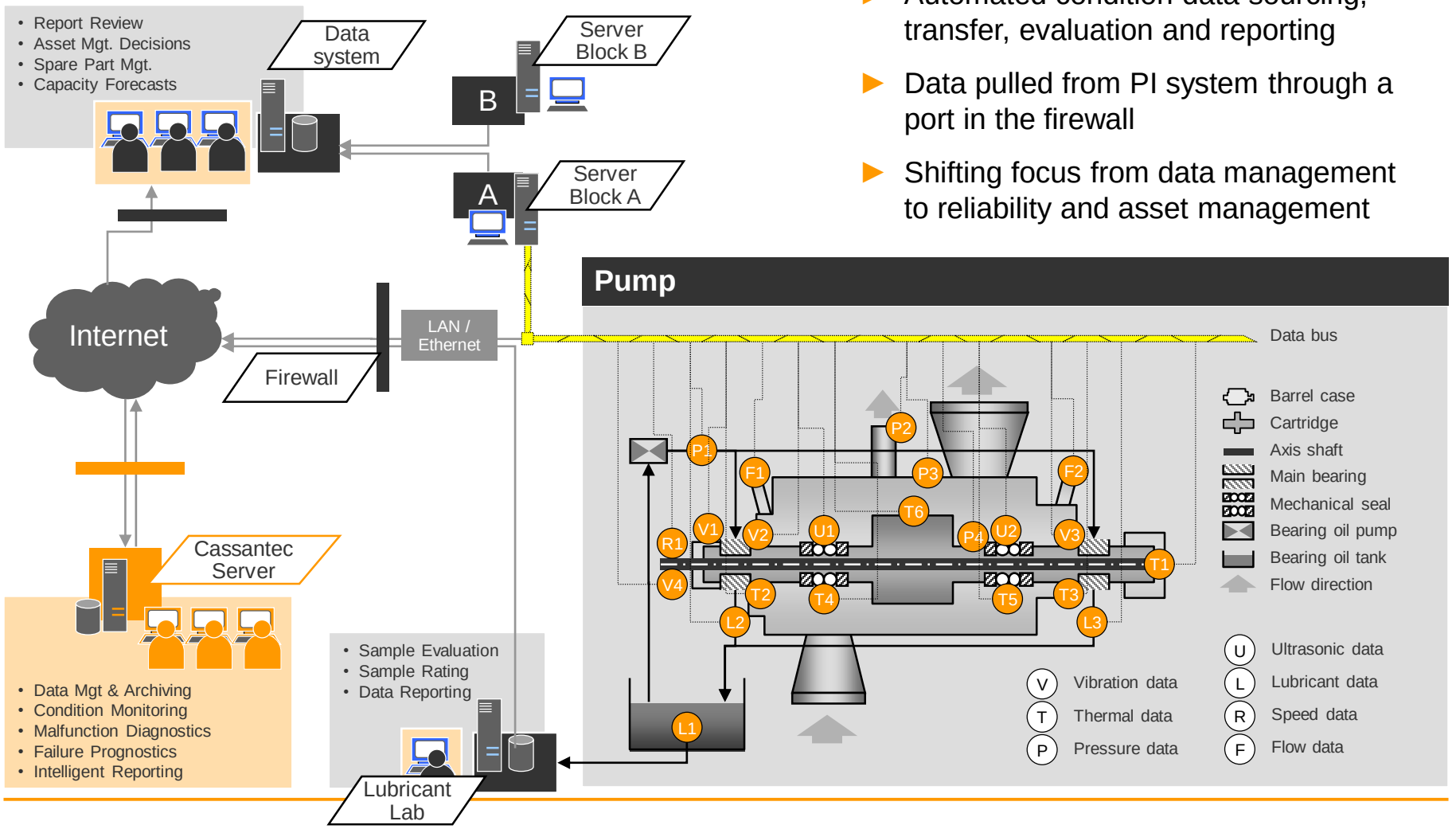
Benefit lever	Applicable?	Comment
Reduce unscheduled maintenance and/or repair	▶ TBD	▶ Are there unscheduled maintenance and repair costs that could be reduced through better foresight?
Shift maintenance into low-cost periods	▶ TBD	▶ Is it possible to use prognostic foresight to schedule maintenance when cost is expected to be low?
Shift maintenance into low-revenue periods	▶ TBD	▶ Is it possible to use foresight to schedule maintenance when revenue from production is expected to be low?
Reduced preventive scope and/or frequency	▶ TBD	▶ Does Δ risk justify Δ cost? (Cassantec computes Δ risk!)
Better maintenance work order preparation	▶ TBD	▶ Does Cassantec provide better foresight and/or diagnostics than current systems?
Preempt damages	▶ TBD	▶ Does Cassantec provide earlier warnings and/or better diagnostics than current systems?
Reduce redundancies	▶ TBD	▶ Does Δ risk justify Δ cost? (Cassantec computes Δ risk!)
Enhance reputation	▶ TBD	▶ Secured position as a quality, reliability and/or availability leader

Reducing 17 unplanned outages to 6 using Cassantec's prognostics on the available acoustic data

Prognostic Report for Steam Boiler



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 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

½ day onsite

2 Specify Malfunction Modes

- Specify malfunction modes
  - ▶ Definition
  - ▶ Detection
  - ▶ Response
- Prioritize malfunction modes
- Correlate condition parameters to malfunction modes
  - ▶ Qualitative
  - ▶ Quantitative

2 days onsite

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.

Cassantec-internal

4 Automate Data Transfer

- Batch Specification
  - ▶ Data sources
  - ▶ Data format
  - ▶ Time intervals
- Configuration and tests

1 day IT

5 Use Forecasts

Unit level:

- Consideration of forecasts in
  - Scheduling
  - Scoping
  - Preparation

  of outages
- Consideration of forecasts in life cycle and retrofit decisions

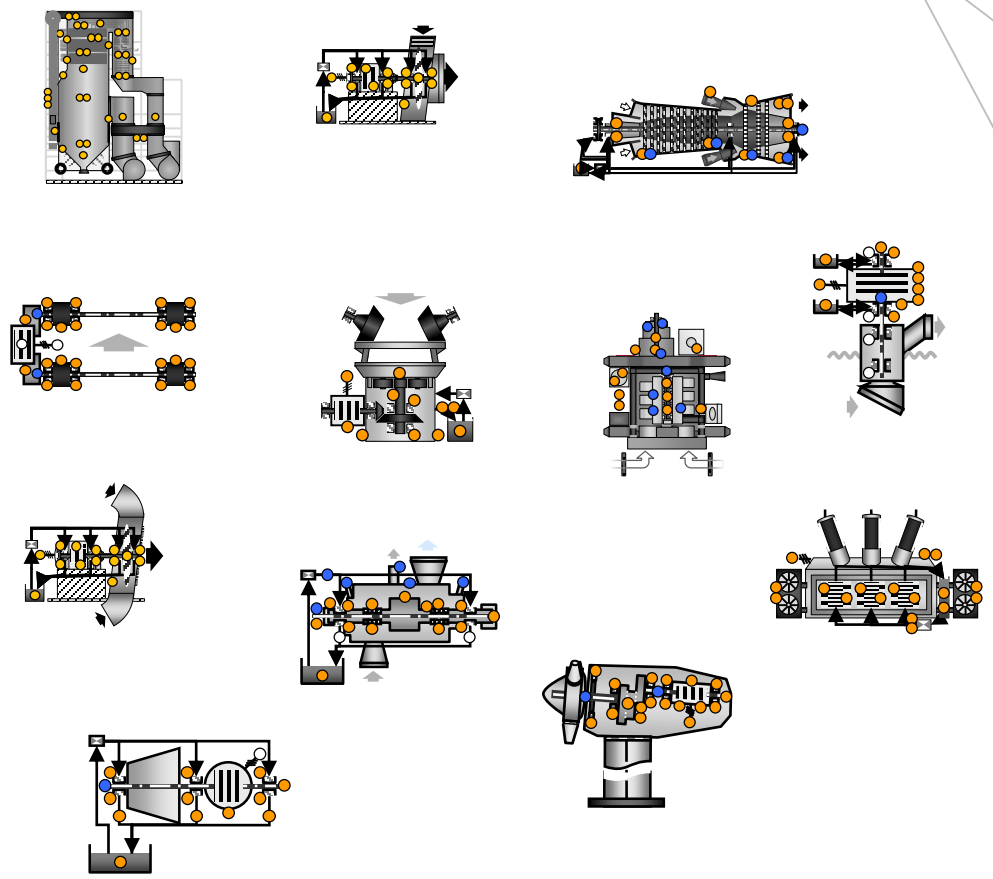
Fleet level:

- Consideration of forecasts in commercial decisions

Ongoing use

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*

1 Introduction of Cassantec

2 Summary

Is Prognostics already part of your routine?

1	Do you incorporate the **future equipment condition** into your maintenance decisions?	Yes ☐	No ☐	Relevant is the **future** condition of an **individual** component rather than the **current** condition or fleet / industry **averages**.
2	Do your forecasts work with **explicit time horizons** and **probabilities**?	Yes ☐	No ☐	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.”
3	Do you use forecasts across **all critical assets**?	Yes ☐	No ☐	Is the prognosis provided by **one** coherent and comprehensive solution rather than having **different** solutions for different assets and **none** for some critical assets?
4	Do you utilize **all types of available data** for forecasting?	Yes ☐	No ☐	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)?

Prognostics Readiness – why it is never too early to start

		Yes	No
1	Do you gather **process data** and **condition data** on your critical equipment?	☐	☐
2	Do you keep **data histories**, e.g. in a historian?	☐	☐

If “Yes” to both:

You are ready for Prognostics!

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

Versus ***Condition monitoring software***	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.
Versus ***Diagnostics*** *and* ***Predictive Analytics***	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*).
Versus ***ERP*** *and* ***asset management software***	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.
Versus ***work order management software***	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.

Diagnostics vs. Prognostics

Diagnostics
answers
what / why / which / where / how

- ***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
answers
when / will

- ***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

Briefing on Cassantec AG

Cassandra
prophet of critical future events in Greek mythology

Meaning:	Cassantec = **Cassan**dra **Tec**hnologies
Launch:	Latest platform launched in 2007, U.S. market entered in 2009
Locations:	HQ in **Zurich**, branches in **Berlin** and **Cleveland**, Ohio
Position:	Independent provider of automated, high-end **prognostic solutions** for industrial asset management
Technology:	Novel combination of mathematical **best practice** techniques backed by proprietary **reference database** from industry partner
Offering:	**Prognostic reports** and **availability forecasts** with periodical updates (subscription) for industrial equipment operators
References:	**Chemical, Power, Transportation, Upstream Oil & Gas** (USA and Europe)
Promoters:	Swiss government (CTI Label), opinion leaders
Industry Partner:	Collaboration with leading U.S. lubricant lab (**Insight Services**) and leading acoustic sensor provider (**Triple 5**)
Academic Partner:	EPFL, Stanford University

Please contact us!

Team

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