How To Proactively Run What You Have Now
Why Care about Prognostics in the First Place?

Whether a conscious effort or an implicit way of making decisions, making prognoses is a daily routine when operating equipment. For example, by scheduling the next planned maintenance in two months, you expect your equipment to be available until then. Likewise, by accepting a customer’s order on a tight delivery schedule, you assume your plant will not fail you. These are implicit prognoses usually based on experience. They are also likely supported by predictive diagnostic insight into the current condition of the equipment and fleet-wide averages derived from original equipment manufacturer (OEM) specifications or mean time between failures (MTBF) analyses.

Prognostics is based on rigorous data analytics, transparently supporting decisions thus far largely based on experience.

Prognostics provides relevant and significant time horizons with explicit risk profiles. This is a step change in comparison to the much less specific and shorter horizons achievable with predictive diagnostics.

Prognostics is calculated for the individual asset based on its unique data, thereby increasing the prognostic accuracy as compared with traditional methods of fleet averages.

The insights gained from prognostics are used to improve operation and maintenance strategies. Remaining useful life (RUL) can be managed and expanded, helping to improve the cost structure of your operations. In addition, downtime for maintenance can be reduced and unscheduled downtime can be especially minimized.

Here is how to prepare for prognostics.

Step 1 : Selecting the Equipment

The first step is to select the equipment for which you would like to obtain prognostic information. Ideally, you should start with an equipment type that:

✓ is truly critical for continuous plant operations;
✓ involves considerable costs and effort in case of malfunction or failure;
✓ generates condition and process data that is being recorded and available for further quantitative processing.

Step 2 : Specifying the Malfunctions

 typically, the list of possible malfunctions for any type of technical equipment is long. It ranges from a steady loss of efficiency and leakages to a complete failure or outage. Even though the equipment keeps running for most of these malfunctions, it is not fully functional or is running below its potential power.
Accordingly, the second step is to specify the **top 10 malfunctions** of the equipment type selected. These could be malfunctions that you have always managed to avoid, possibly almost literally at all cost. You also could have observed them over the last five to 10 years. Whatever the case may be, be sure to consider the true root cause of the malfunction at hand and how you typically detect it in the data.

### Step 3 : Reviewing the Data

After having specified the top priority malfunctions and their related data, you can move on to exporting a data history from the historian. The length of the data history needed for prognostics varies depending on the prognostic horizon demanded and the type of malfunction. As a rule of thumb, three to five years is considered ideal.

To make sense of the data, you can now visualize it over time and try to detect patterns that explain malfunctions. Since many data patterns are hard to identify, applying advanced stochastic methods probably will be required.

Questions that can help you accomplish this step include: Can I formulate data diagnostic rules that would be helpful for detection before the malfunction occurs? What alarm thresholds, limits and benchmarks would I have to apply for detection?

Make sure you verify what you observe in the data is reasonable by involving engineers from the plant.

### Step 4 : Formulating the Parameters and Correlating Malfunctions

In this step, correlations of data to particular malfunctions must be specified. At this point, make sure to carefully distinguish between direct and indirect causal relationship. You may formulate useful condition parameters that reflect your diagnostic rules of thumb involving arithmetic or logical functions. During this process, consider the period of data observation and make sure to observe contingencies and dependencies on other rules. Furthermore, a set of value ranges has to be determined for the parameters formulated.

### Halfway Prognostics Checklist

- **Do you know your equipment?**
  - Did you select the truly critical equipment in Step 1? [Y/N]
  - Did you find consensus on the top 10 malfunctions in Step 2? [Y/N]
  - Have you been able to specify these malfunctions in Step 2? [Y/N]

- **Do you own the right data?**
  - Have you been able to download and review the data in Step 3? [Y/N]
  - Does it cover a sufficient time frame? [Y/N]
  - Do you have data related to all malfunctions from Step 2? [Y/N]

- **Do you master diagnostics?**
  - Did you find consensus on parameters in Step 4? [Y/N]
  - Can you compute these parameters with the given data? [Y/N]
  - Do the parameters relate to at least one of the malfunctions? [Y/N]

If you answered “Yes” (Y) to all these questions, you are ready for the next steps that go beyond current insights to obtain foresight on equipment condition.

### Step 5 : Computing RUL

Step 5 consists of several computational operations that require advanced knowledge of data analytics. To be explicit, in this step, the condition and process data, as well as the complementary malfunction and parameter specifications, need to be fed into a stochastic model. Highly specialized software vendors or online service providers support this step and can provide an end-to-end solution. The following computations should be accomplished during Step 5:

- Projection of equipment condition over an explicit prognostic time horizon.
- Application of diagnostic rules at different future time stages.
- Inference of malfunction likelihoods based on prognostic and diagnostic results.
- Obtaining a set of malfunction-specific RUL distributions.
- Consolidation of the result to a total RUL distribution for the equipment.
- Conversion of the distribution to a meaningful illustration for maintenance planning.

### Step 6 : Validating Results

In this step, it is crucial that you ensure the plausibility of the results. For example, a check can be done by conducting a retrospective analysis. This allows you to validate the results with empirical observations from the past. Additionally, it is useful to continuously monitor the prognostic results and ascertain their plausibility.

### Step 7 : Utilizing the Foresight

To best use your results, you can now analyze how your current reliability management processes can be leveraged using the insights from prognostics. As a result, the newly gained transparent information about future risk profiles will help you improve your operations and maintenance. For example, you can bundle maintenance work into clusters, thereby reducing your downtime. You can also increase the efficiency of your maintenance scheduling by making use of longer visibility into the future and selectively migrating from preventive or reactive to truly condition-based schedules.

Some useful questions that can assist you at this stage are:

- How can I adjust my maintenance schedule so I trigger the maintenance when the equipment condition really warrants it?
- How can I use the insight from prognostics to prevent my equipment from wearing out more quickly than necessary?
- Would it help to adjust the operation strategy of the equipment so the RUL can be prolonged while keeping operations running smoothly?

### Reaping the Benefits from Your Prognostic Efforts

After applying the seven steps, you will immediately gain new understanding of your equipment and probably come across opportunities to technically optimize your condition monitoring. After gaining some experience in handling prognostics, you soon will be able to convert most of your unscheduled downtime into scheduled maintenance. In the mid to long run, prognostics enables you to create commercially optimal condition-based maintenance schedules.
Case Study
How Prognostic Analysis Was Used to Prolong RUL at a Hydroelectric Power Plant

A Swiss power producer was concerned about the remaining useful life (RUL) of the aging equipment in one of its hydroelectric plants. Applying the prognostic methodology described in this article, historical vibration, temperature measurements and process data were used to prognosticate the condition of various critical assets.

During the data analysis, statistically significant trends in the condition data for one of three generators were identified. This prompted an in-depth examination, which revealed a notable increase in vibration displacement of the generator’s bearing over time. A subsequent scenario analysis established a dependency between the development of the vibration displacement and the power level at which the generator is run.

This alerted the operator to adjust the current operations strategy. It turned out that operating that generator below a specific threshold would significantly prolong its RUL. Since the lost output of this generator could be switched to the other two healthy generators, this strategy could be accomplished without a drop in overall power production. Thus, while still allowing the generator to operate at a considerable capacity, this simple adjustment helped increase the RUL of a mission critical component and, thereby, the entire plant.

In addition, the operator now has advanced knowledge of when a replacement is likely to become necessary. Based on this newly acquired insight, maintenance scheduling for all plant equipment was improved. Operations are now more reliable and predictable, with a notable positive impact on the maintenance budget.