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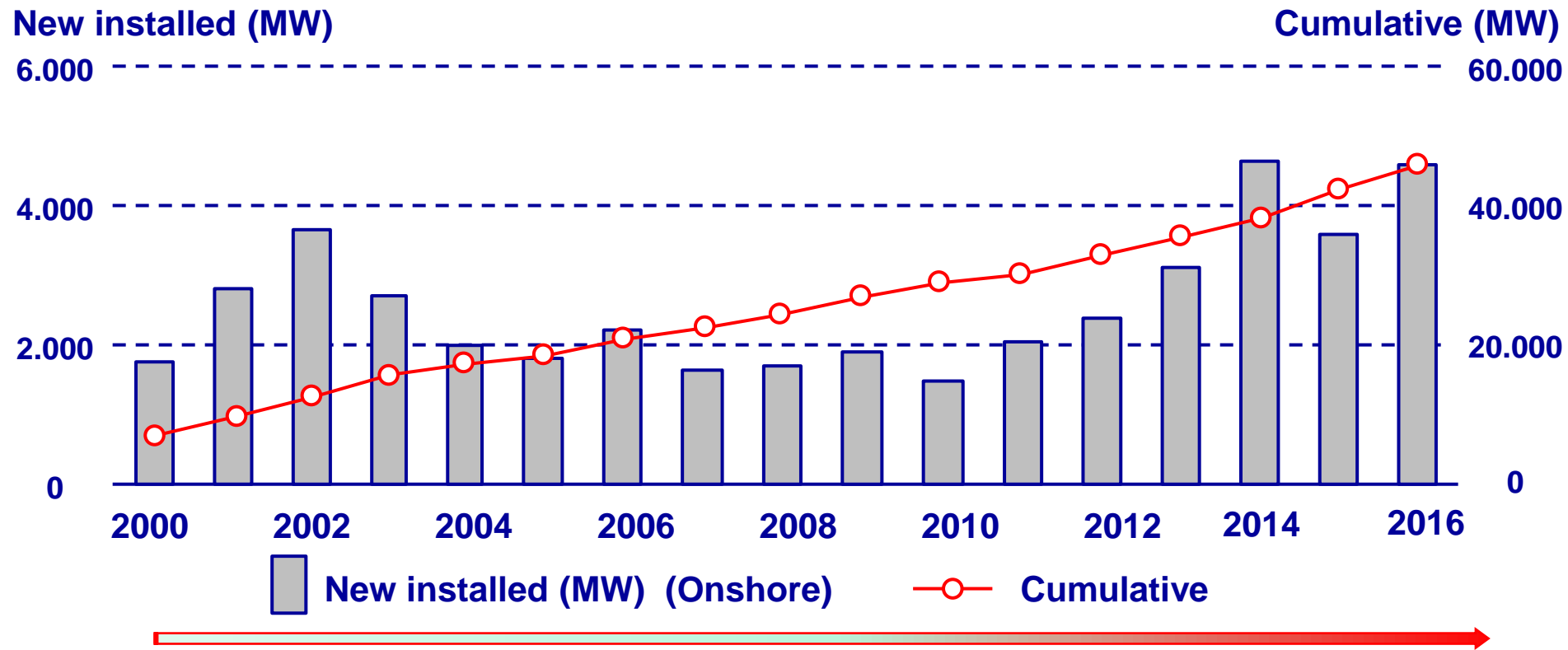
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**Monitoring of concrete bases of wind turbines with
modern inclinometers: Approaches and experience**

- 1. Wind energy - Current development**
- 2. Condition monitoring vs. technical assessment**
- 3. Application of inclination sensors (example)**
- 4. Conclusions**

Wind energy - Current development

Wind energy is the largest source of electricity production from renewable energy in Germany. Currently there are more than 24 000 wind turbines in use.



Source: www.wind-energie.de

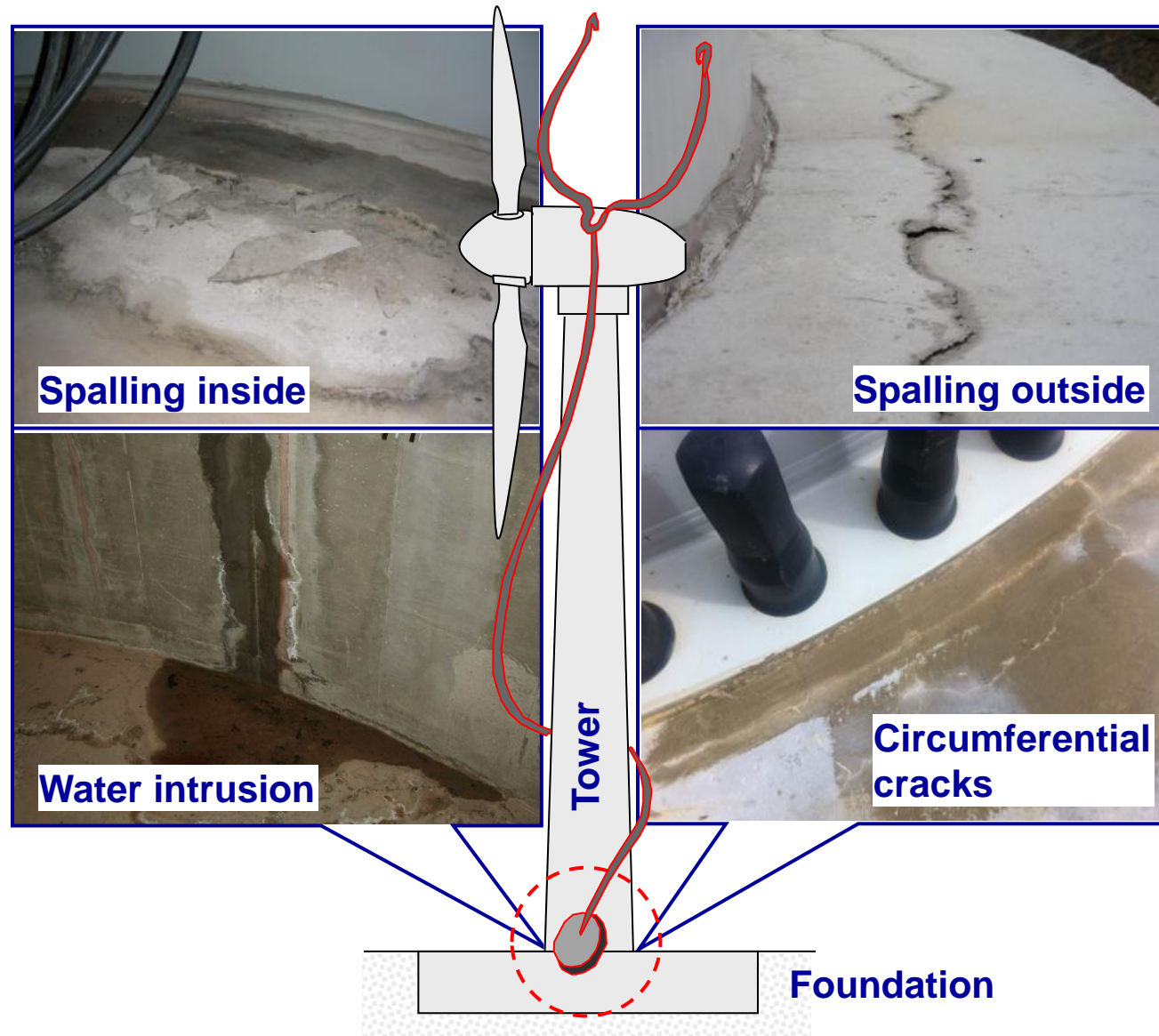
14 – 17 years

More than 10 000 of these wind turbines were built before 2003 and reach the limits of their planned lifespan over the next few years. Therefore, control of their bearing structures plays a particularly important role now.

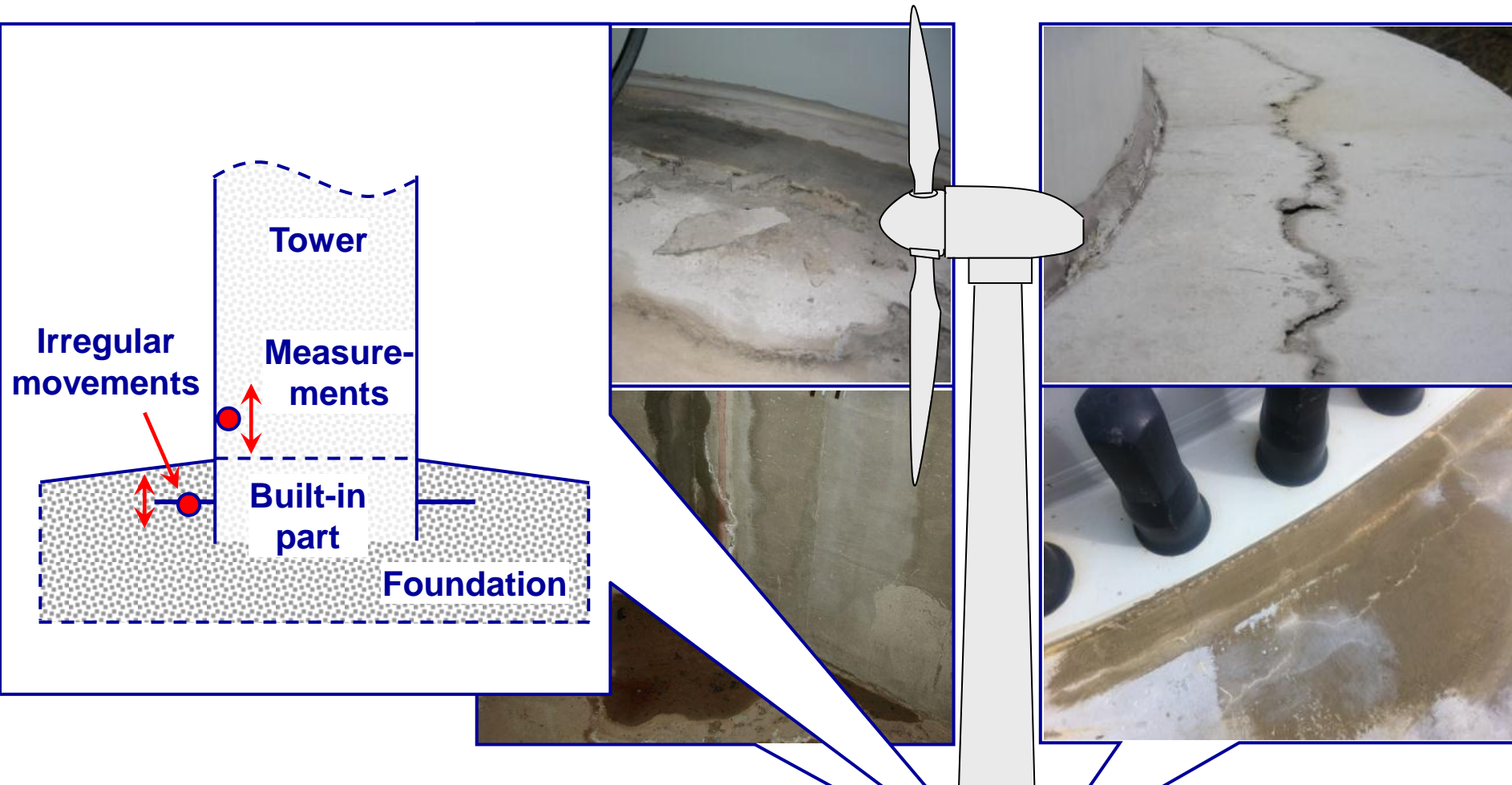


Typical foundation defects in wind turbines

The increasing number of foundation defects in wind turbines shows that one of the main problems is the connection between the tower and the foundation. The damage symptoms are the cracks or spalling in the top of the foundation as well as the water intrusions inside the foundation.



Control of irregular movements of built-in parts



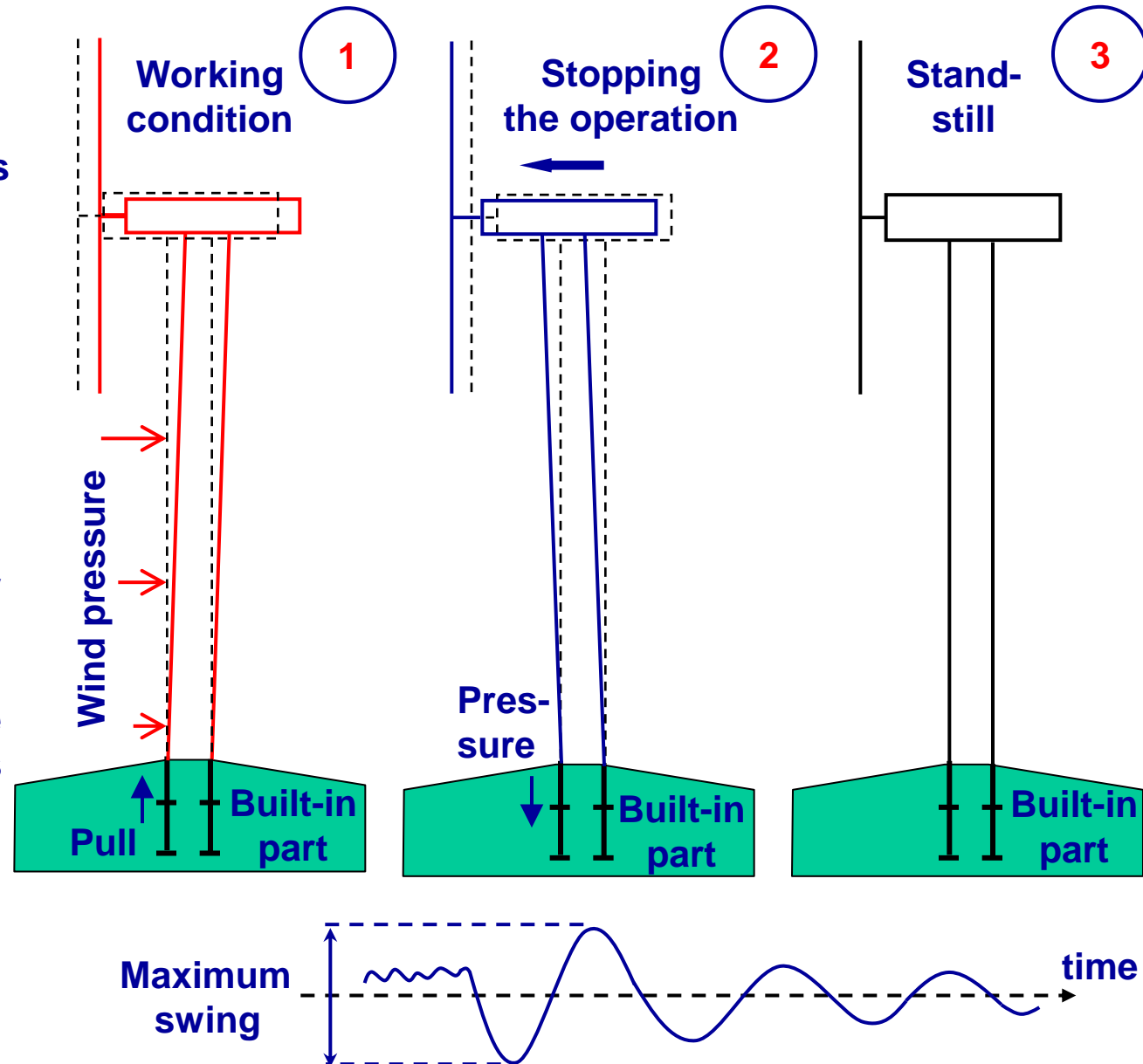
The aim of the measurement is to control the irregular movements of the built-in part of the tower. Unfortunately, it is impossible to measure within the foundation. Measurements on its surface and at the tower provide the important information about the connection between both parts.

Technical assessment - Dynamic stress test (example)

Inspection of a wind turbine is a periodic check of its important parts. In the case of bearing constructions this is as a rule a visual check. Special measurements such as dynamic stress test are only required for selected endangered constructions.

A dynamic stress test:

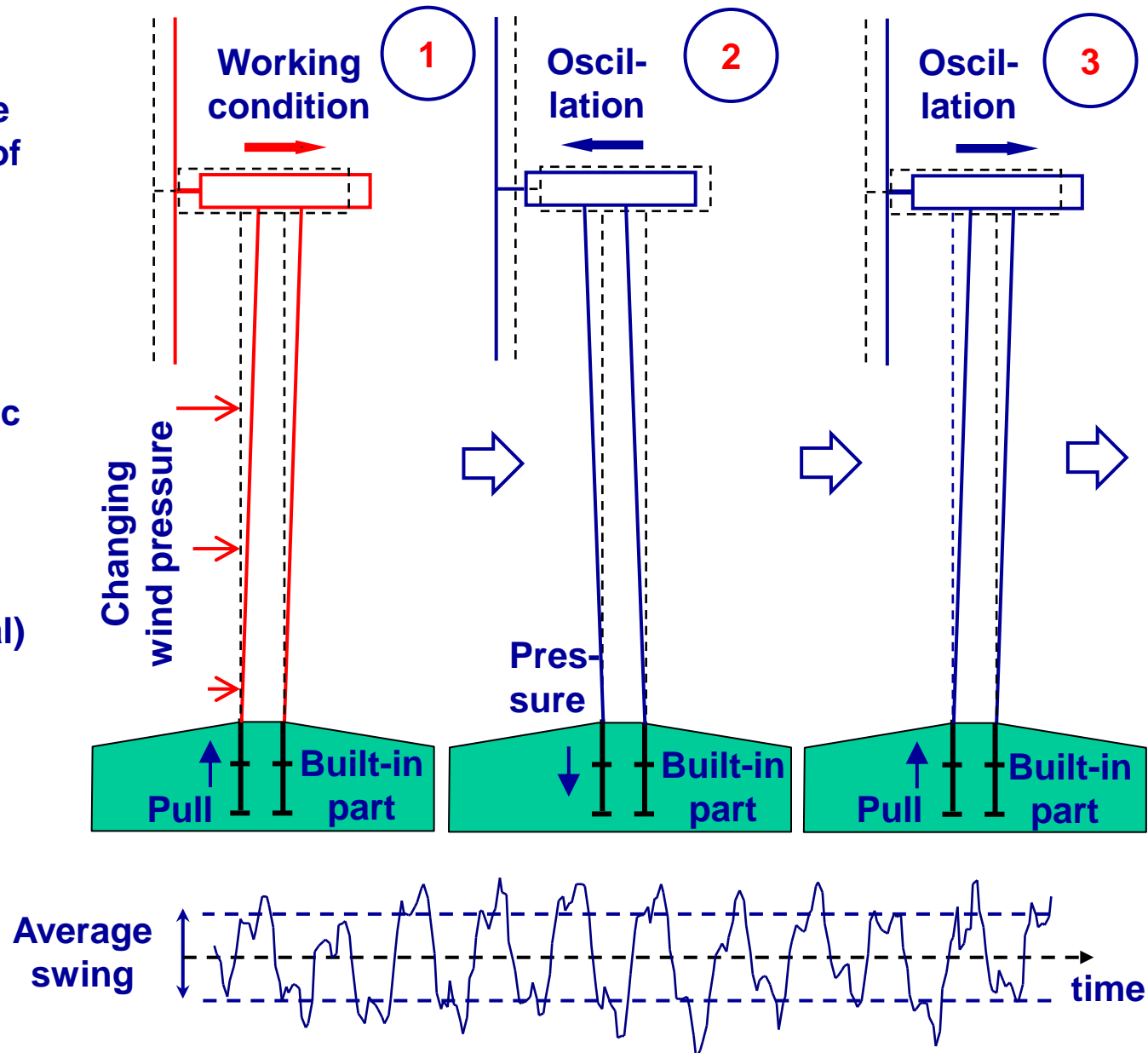
The impulse generated at the rotor after an emergency stop is introduced into the tower and via the built-in part into the foundation. The corresponding deformations (for example the maximum swing) between both parts can be measured and interpreted.



Condition monitoring - Detection of dynamic deformations

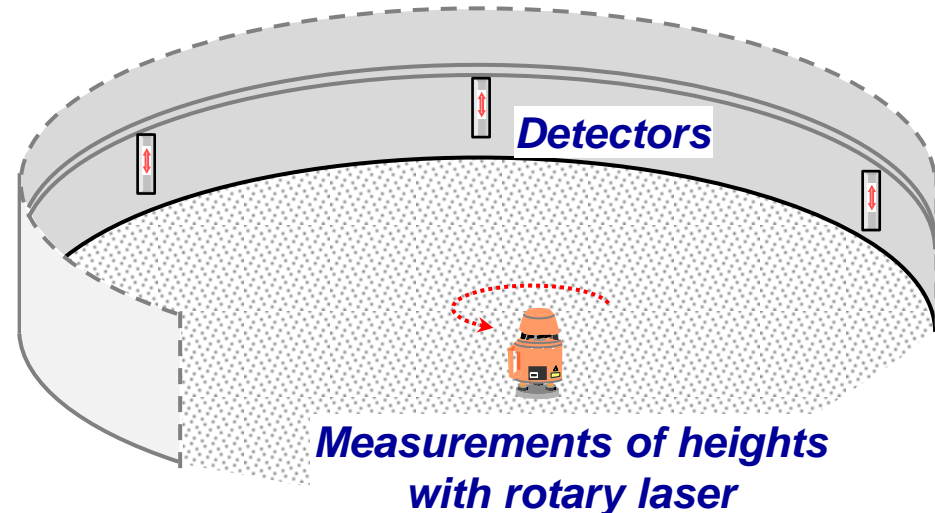
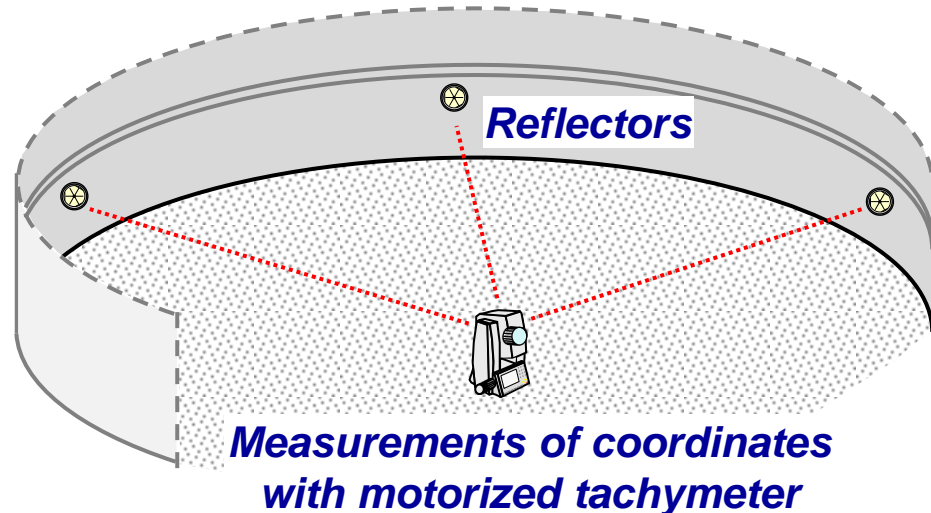
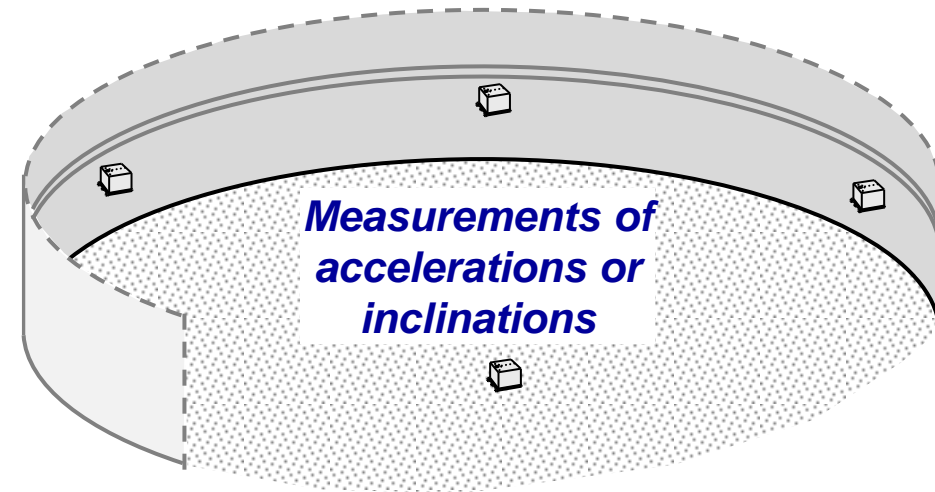
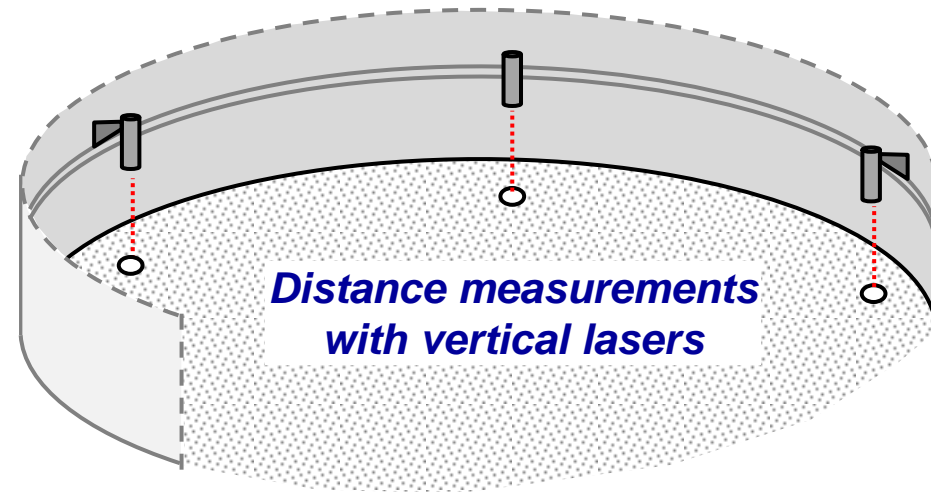
Condition monitoring is the continuous measurement of different parameters of machines, in order to identify a developing fault.

Contrary to special dynamic stress test, the usual movements between the tower and the foundation (for example the average swing over the time interval) can be recorded and analyzed for a condition monitoring.



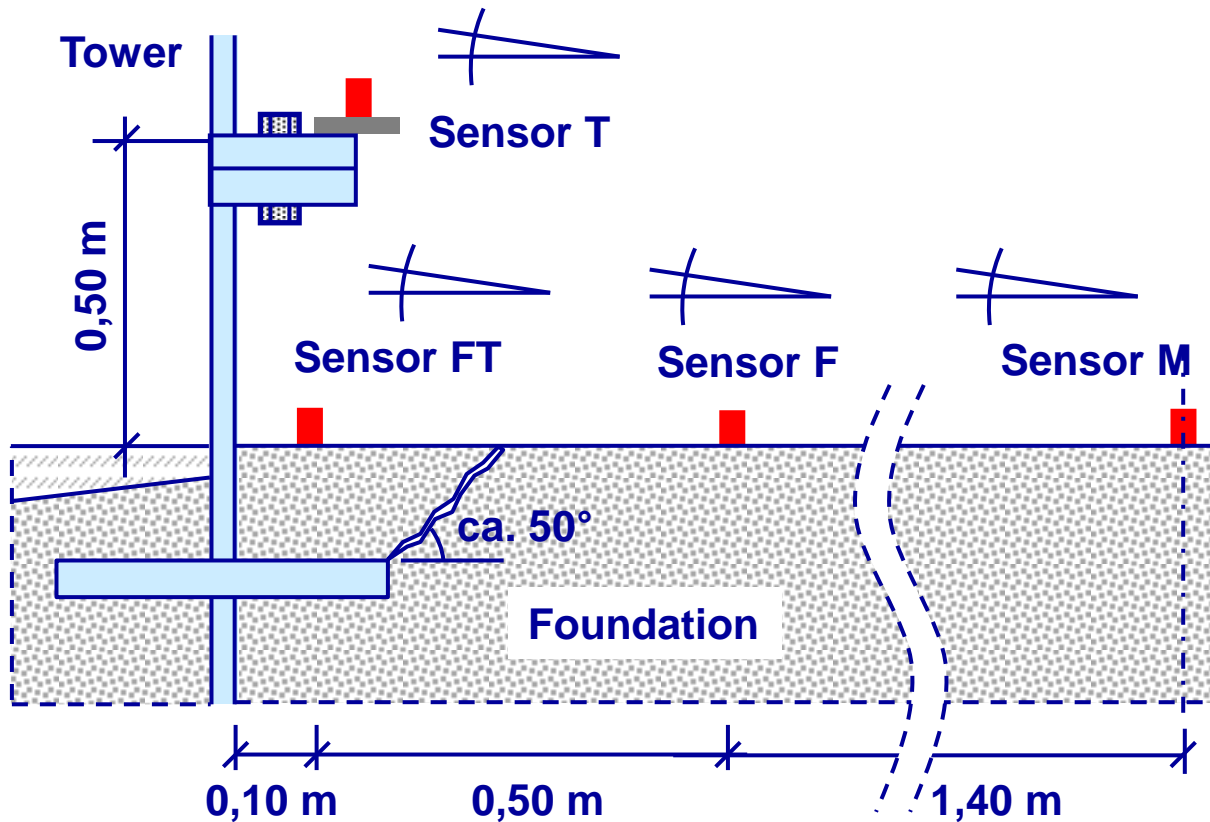
Measuring systems for control of irregular movements

Different measurement technologies for control of the connection between tower and foundation have been tested by myself in recent years.



Measurement system based on inclination sensors (example)

The here described system is based on several inclination sensors that are situated on the foundation inside the tower and are connected to a measurement computer.



Sensor T

Sensor FT

Sensor F

The choice of measurement locations is as important as the choice of measurement equipment. Example:

Sensor T - the base of the tower,

Sensor F - foundation, in the distance to tower,

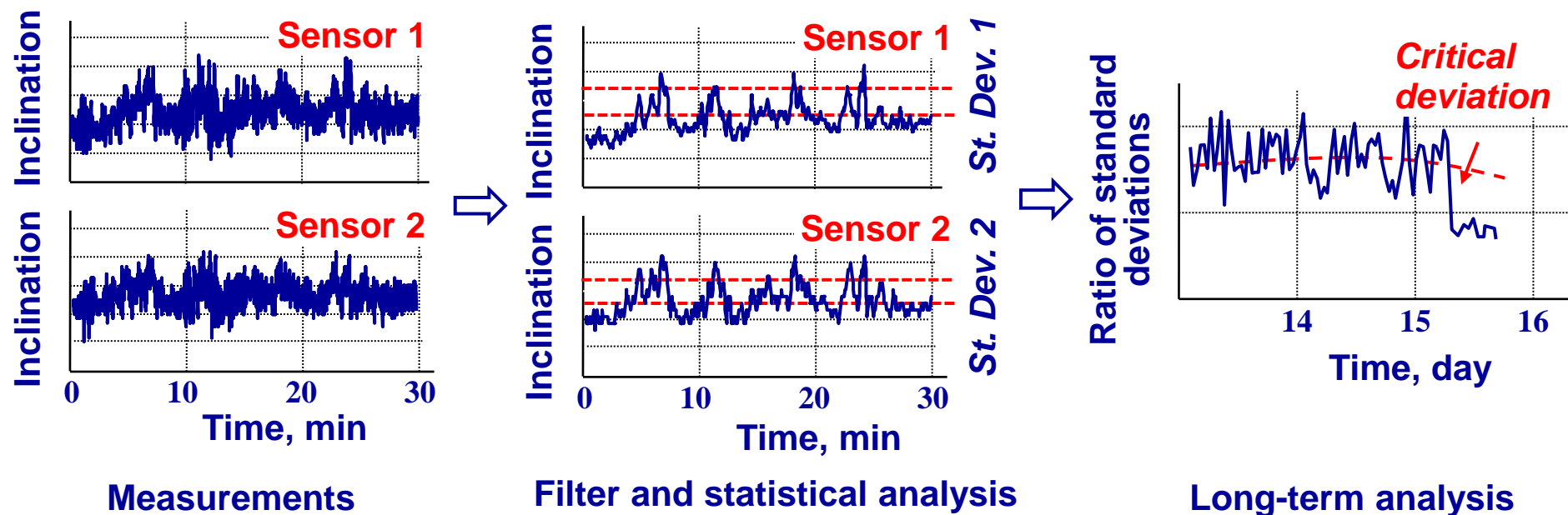
Sensor FT - foundation, near the tower,

Sensor M - foundation, in the middle of the tower.

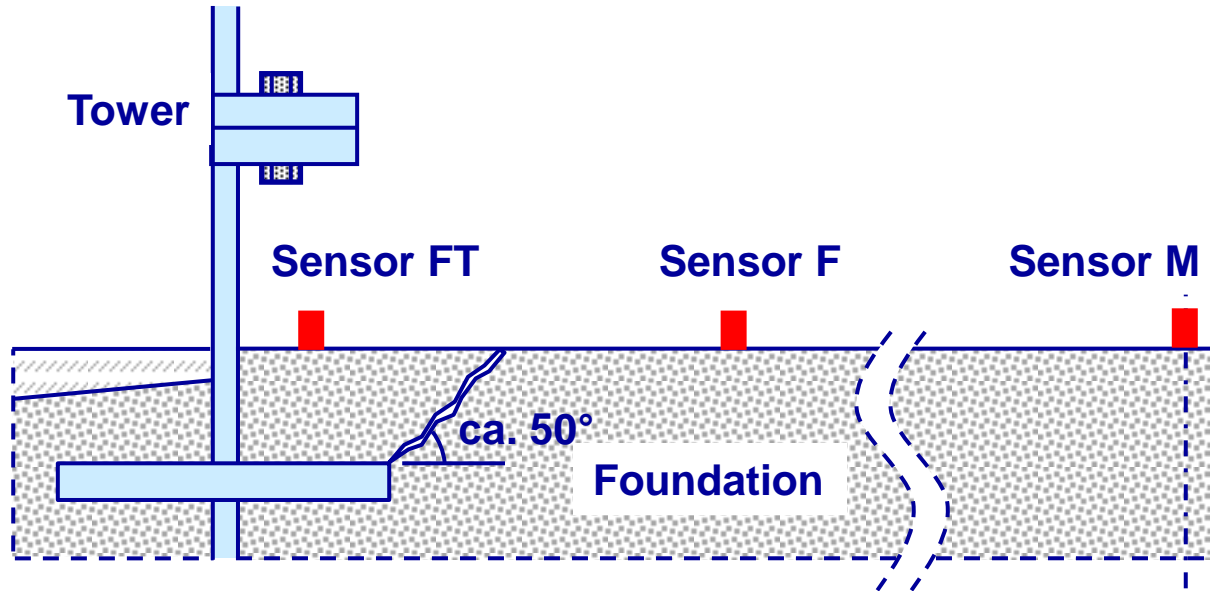
Concept of data analysis for Condition Monitoring

It is known that the quality of monitoring is highly dependent on the applied processing algorithms. We have developed a special method for these purposes:

The signal's energy and therefore its amplitude decreases during its propagation in the foundation. The different defects cause more losses of energy. Therefore, the differences between standard deviations can be used for a check of its condition.

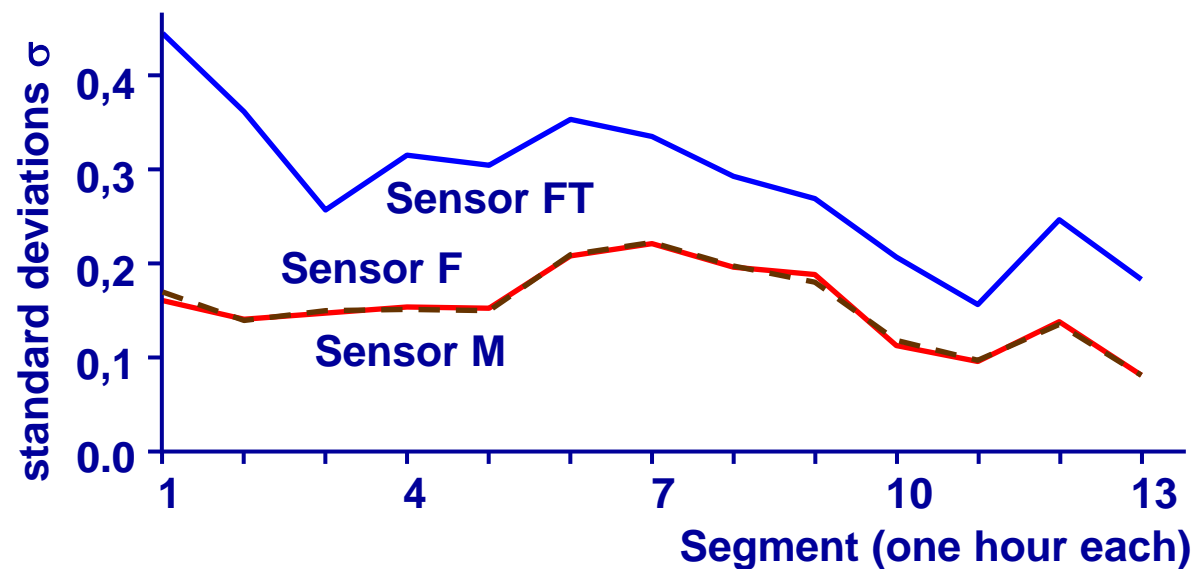


Results of selected test measurements



1. Based on the results it can be assumed that there are significant differences and considerable defects between Sensors F and FT.

2. Based on the results it can be assumed that there are no significant differences and defects between Sensors M and F.



Conclusions

- Many wind turbines will be reaching the limits of their planned lifespan in the next couple of years. The control of the foundation stability is more important for these turbines.
- Several measurement technologies can be used to control the foundation. The measurements in different wind turbines in recent years showed a great potential of the presented method to identify defects with inclination sensors.

Thank you very much for your attention!

**Please send me an email if you need further information:
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