SHM (Structural Health Monitoring)

From a regulatory requirement to a cost saving tool for periodic inspections – a roadmap

presented by Jens Krieger

SHM: real world example

Monitoring aims have to be clearly defined

e.g.

- Fulfill formal requirements
- Life time prolongation
- Complementation of periodic inspections

Impact →	1	2	3	4	5
Probability ↓	Negligible	Minor	Moderate	Significant	Severe
(81-100)%	Low Risk	Moderate Risk	High Risk	Extreme Risk	Extreme Risk
(61-80)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk
(41-60)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	High Risk
(21-40)%	Minimum Risk	Low Risk	Low Risk	Moderate Risk	High Risk
(1-20)%	Minimum Risk	Minimum Risk	Low Risk	Moderate Risk	High Risk

Basis for the definition of the monitoring aims should be a risk assessment

SHM: real world example

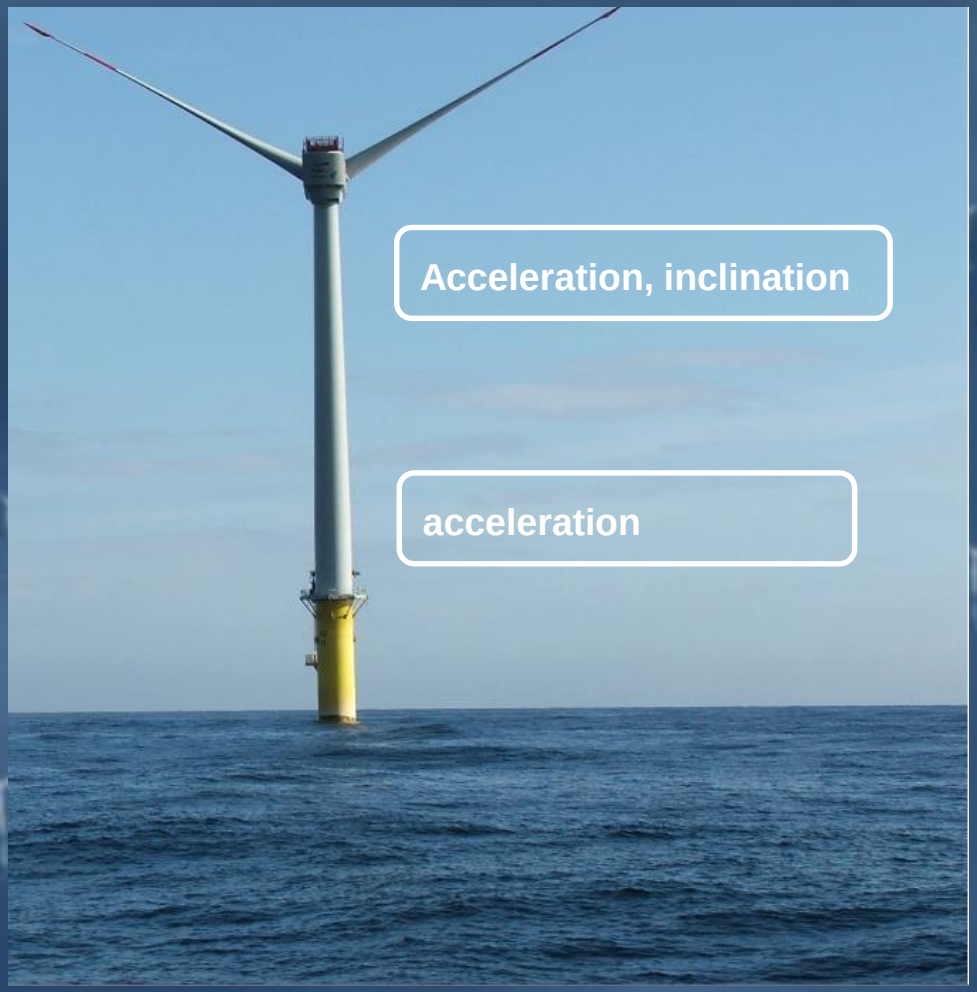
Monitoring aims: more examples

- Structure condition
- Structure safety
- Load monitoring (ultimate, fatigue, usability)
- Life time prolongation
- Complementation of periodic inspections
- Fulfill formal requirements
- Hot spot monitoring
- Data for maintenance operations
- Feedback to design

SHM: real world example

Source of photograph: BSH

SHM: real world example



- Global Monitoring for Robust Structures
- Ambient Vibration Monitoring is Existing Technology
- Model Based Observer for Data Interpretation

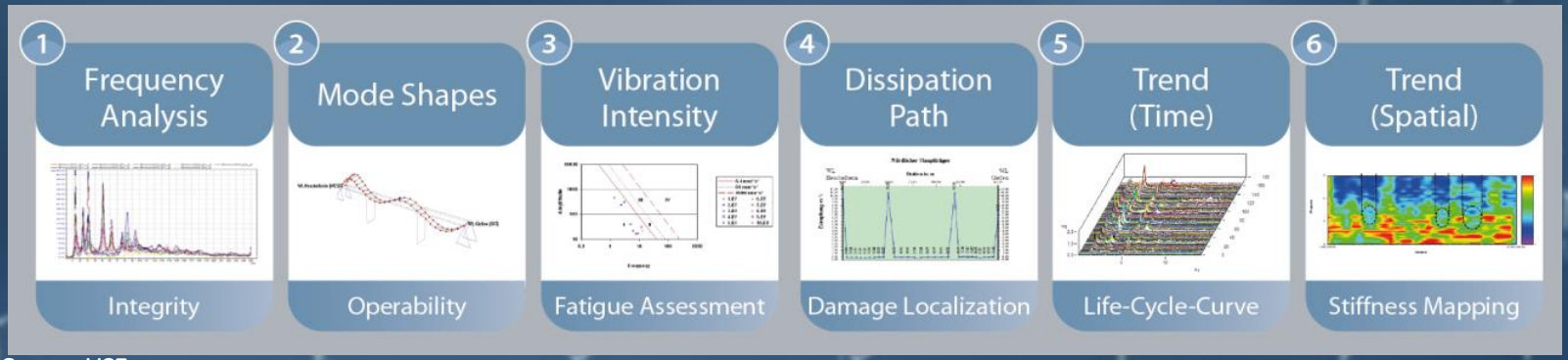
Permanent Monitoring System

- **Few sensors only**
- **Accessible positions**
- **Lower operational costs**

SHM: real world example

SHM: real world example

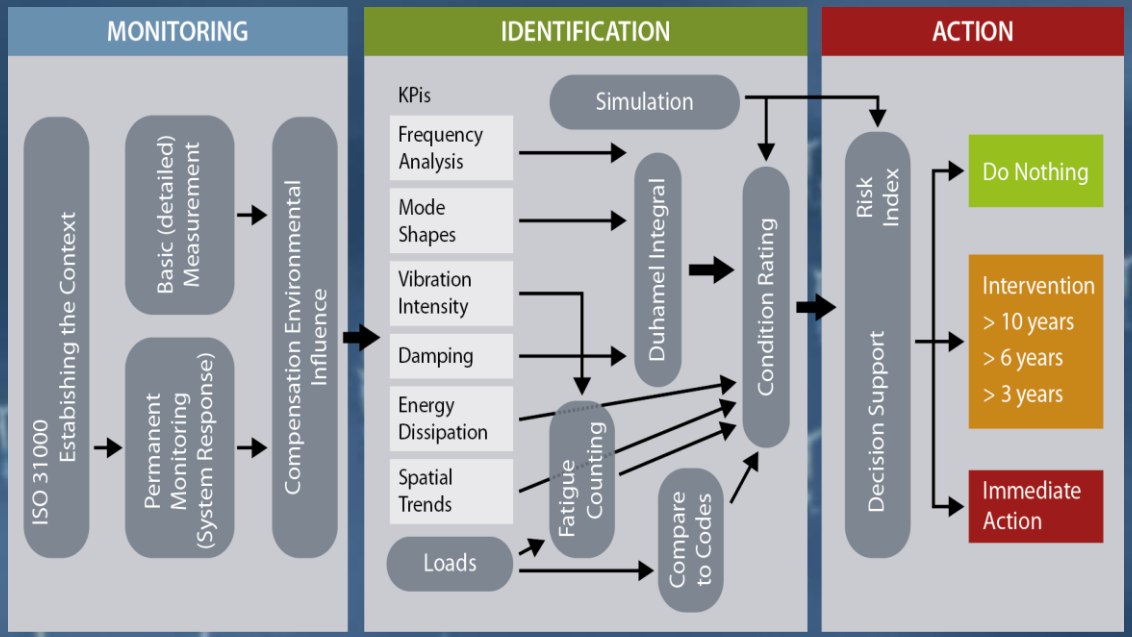
Online calculation of KPIs to reduce data



Source: VCE

SHM: real world example

A Risk Index for Decision Making



Source: VCE

- Ultimate Loads
- Fatigue
- Cracks
- Welded Joints
- Grout Connections,
- Scour
- Corrosion

BSH Standard 2007 vs 2015

	2007	2015
SHM	…Darstellung der geplanten Überwachung der Tragstruktur durch ein Condition Monitoring System (CMS) für mindestens 1/10 der Offshore-WEA…	…Zur Überprüfung des Gesamtverhaltens der Gründungselemente wahrend der Betriebsphase sind an repräsentativen Standorten für Offshore-WEA, die in Abstimmung mit dem Sachverständigen für Geotechnik ausgewählt werden, im Bereich der Gründungselemente Größen wie Verschiebungen, Verformungen, Bauteilspannungen oder Frequenzen zu messen und aufzuzeichnen (Monitoring)….

BSH Standard 2007 vs 2015

	2007	2015
WKP	…Die Intervalle für Wiederkehrende Prüfungen sind festzulegen. Wiederkehrende Prüfungen sind jährlich an 25% der Offshore-WEA eines offshore Windenergieparks durchzuführen…	…Für Offshore-Strukturen werden durch die Lage der zu prüfenden Teile und deren unterschiedliche Qualitat (z. B. konstruktive Sicherheitsfaktoren) unterschiedliche Prüfinterintervalle zu Grunde gelegt. Basierend auf den Prüfergebnissen können diese Prüfintervalle nach einer entsprechenden Laufzeit und Häufigkeit der Prüfung durch einen Antrag auf Abweichung angepasst werden…

Future Standard

Strukturüberwachung und Beurteilung von Windenergieanlagen und Plattformen
Vorsitz: Prof. Dr.-Ing. Werner Rücker, Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin
Eine Richtlinie (VDI 4551) wird zurzeit erarbeitet.

Inspections are Expensive

Inspections
(difficult to make them meaningful)

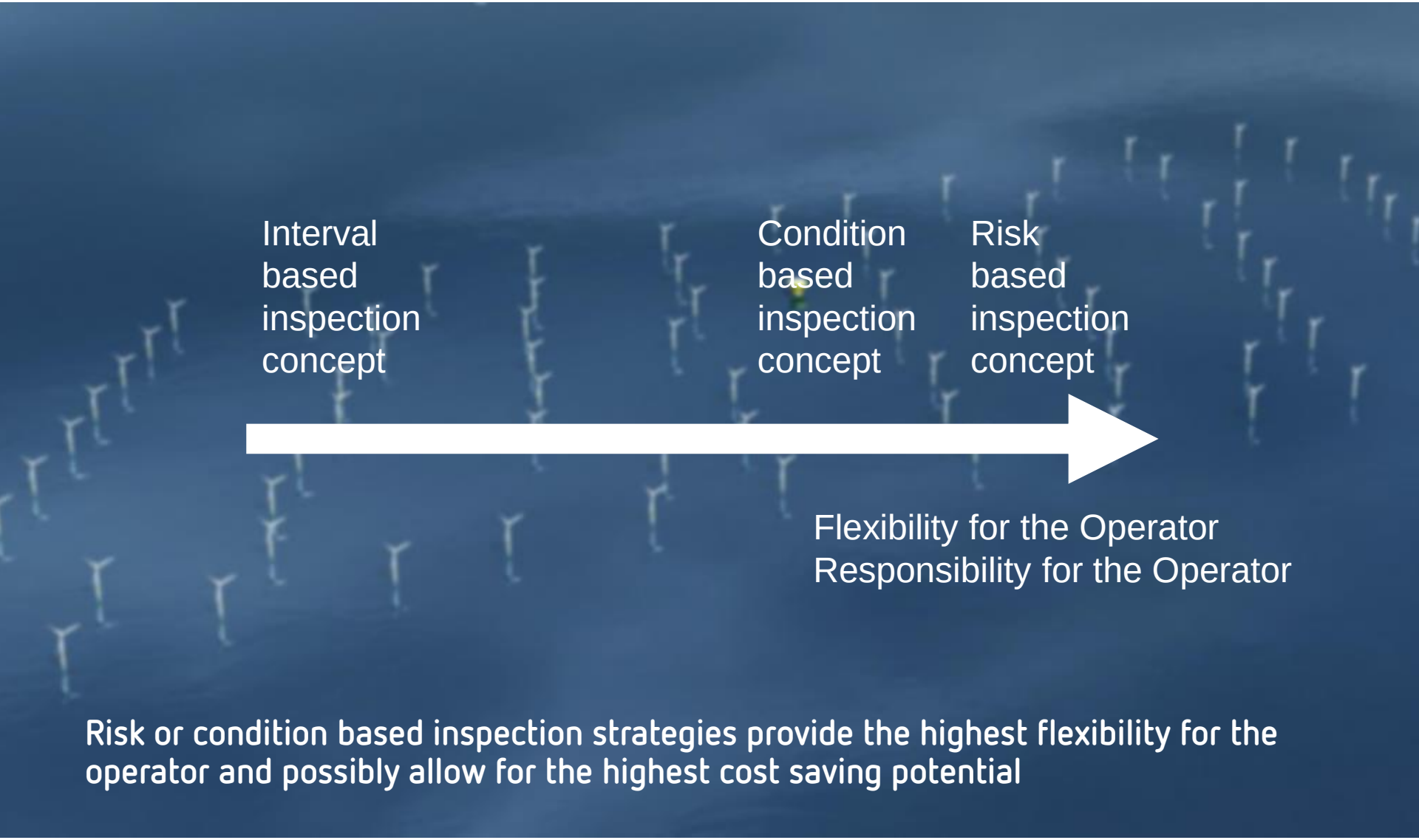
Copyright: www.mssa.org

Source: VCE

WKP and SHM in the BSH Standard

		WKP	SHM
Tragwerk	Anodischer Korrosionsschutz, Schweissnähte, Kolk, Meeresboden, Mariner Bewuchs, Korrosionsschutz	vorgeschrieben	+
Gründungs -elemente		-	vorgeschrieben
Rotor-Gondel-Baugruppe	Rotorblatt, Triebstrang, Maschinenhaus, Hydraulik, Sicherheitssysteme	vorgeschrieben	
OSS	Lasttragende Strukturelemente, Sicherheitsrelevante Strukturelemente, Meeresboden, Mariner Bewuchs, Anodischer Korrosionsschutz, Korrosionsschutz	vorgeschrieben	+

Inspection Strategies



Risk or condition based inspection strategies provide the highest flexibility for the operator and possibly allow for the highest cost saving potential

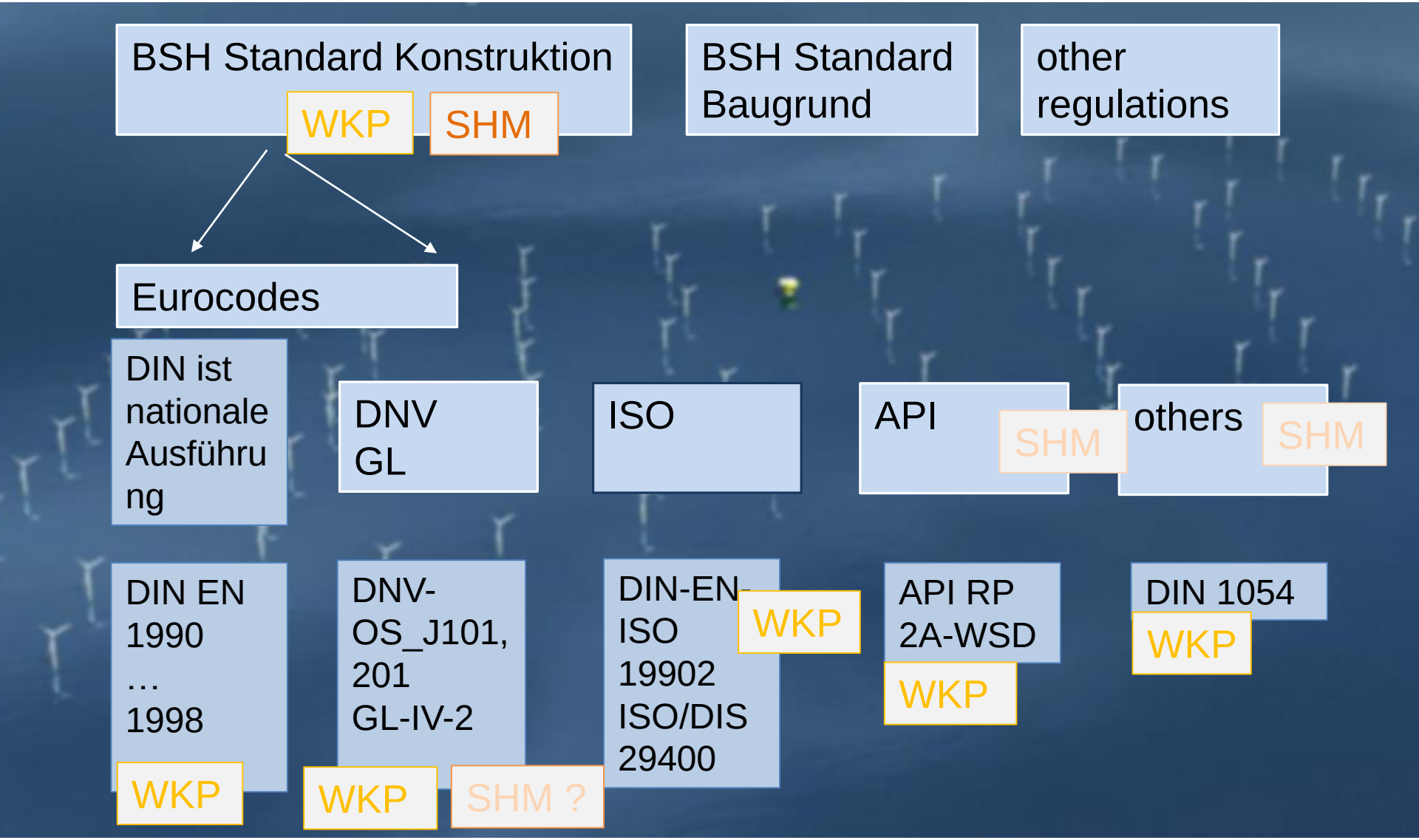
Future Standard: Risk Based Inspection

Date: 2014-01
CEN/TC 319
Secretariat: NENUNI

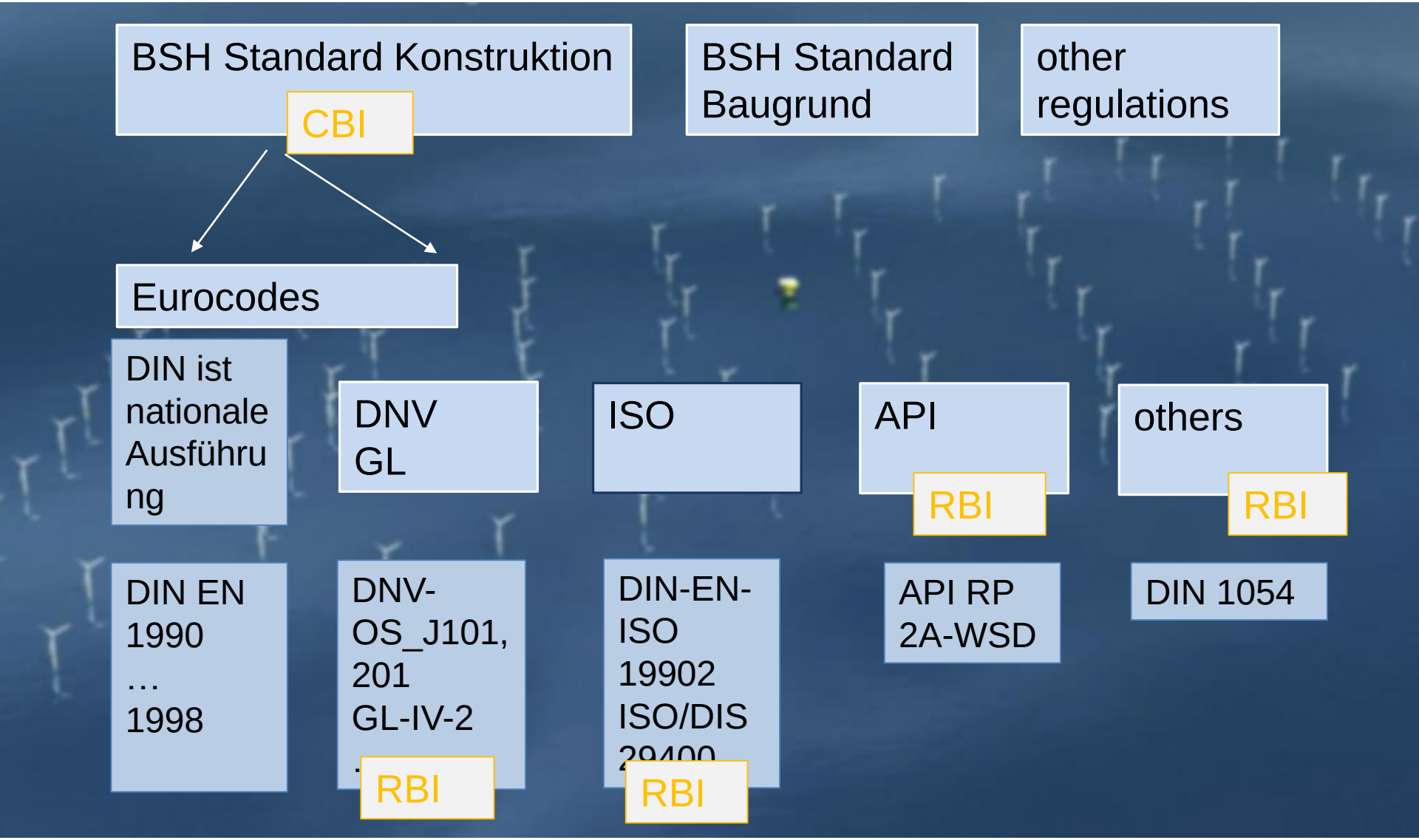
Risk-Based Inspection Framework

Document type: European Standard
Document subtype:
Document stage: CEN Enquiry
Document language: E

Technical Regulations Construction of Offshore Wind Turbines

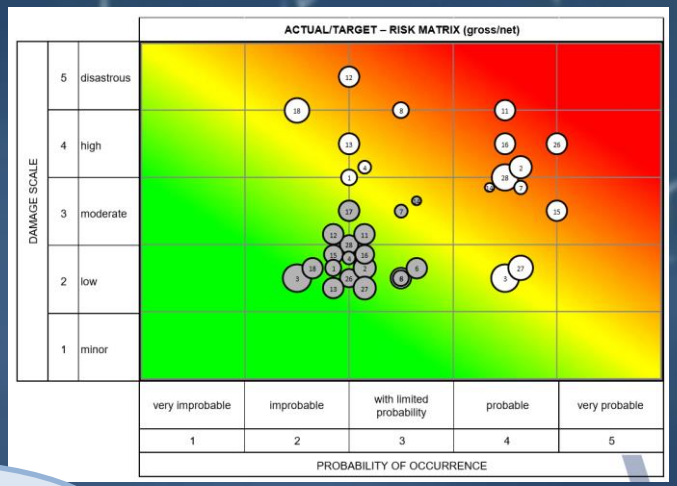


Technical Regulations Construction of Offshore Wind Turbines



Design Triangle

Design



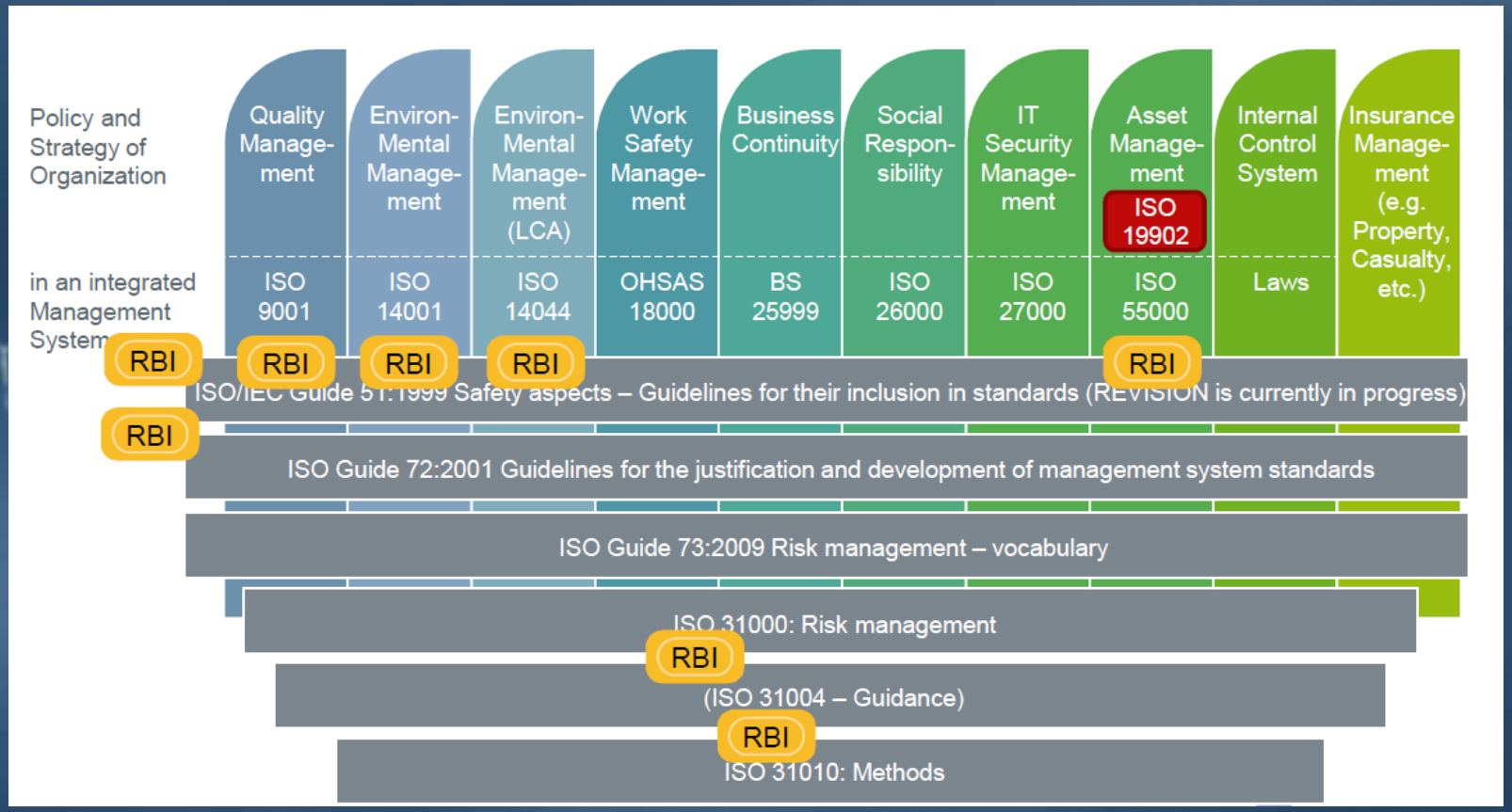
Risk matrix and
risk mitigation plan

Inspections

CM

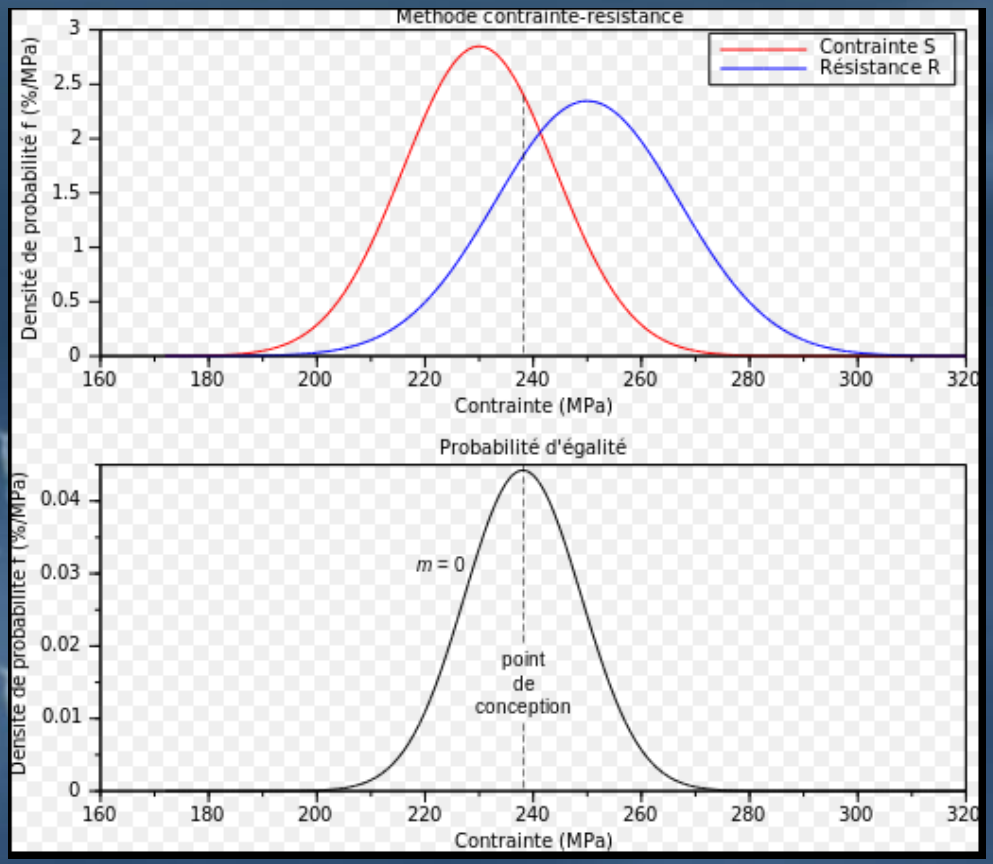
Risk is the basis of all decision making.

Risk Based Inspection and Asset Management



Source: SafeLife-X

Risk in Civil Engineering



source: Wikipedia, Stress-Strength Analysis

CM has to relate to the engineering world.

Summary

Status Today

- Authority Requirement
- State of the art is still not defined
- SHM can be used in periodic inspection
- There is potential for savings
- ‚The doors are half open‘

Future

- VDI 4551
- Risk Based Inspection Framework
- Paradigm shift to more flexibility/responsibility for the operator