GENERATION

# Drivers for Owners and Operators of Onshore/Offshore Wind Turbines


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EDF Energy: Coal, Gas and Renewables


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Workshop on NDT and SHM Requirements for Wind Turbines
OREC, Blyth

# Agenda

- EDF Renewables Fleet
- Challenges
- Examples of problems, impact and solutions
- R&D: Exploiting opportunities, Planning for the foreseeable
- What does the end user require
- View on SHM and NDT

# EDF Overview: Renewables

EDF's aim is to be an efficient responsible electricity company that champions low-carbon growth

Part of this strategy is based on accelerating the development of renewables generation and guaranteeing the safety and performance of existing and new-build nuclear facilities

Target of 50GW of renewable energy by 2030 (Wind, Hydro, Solar, Marine), other opportunities such as Biomass, heat recovery, geothermal via affiliates (Dalkia).

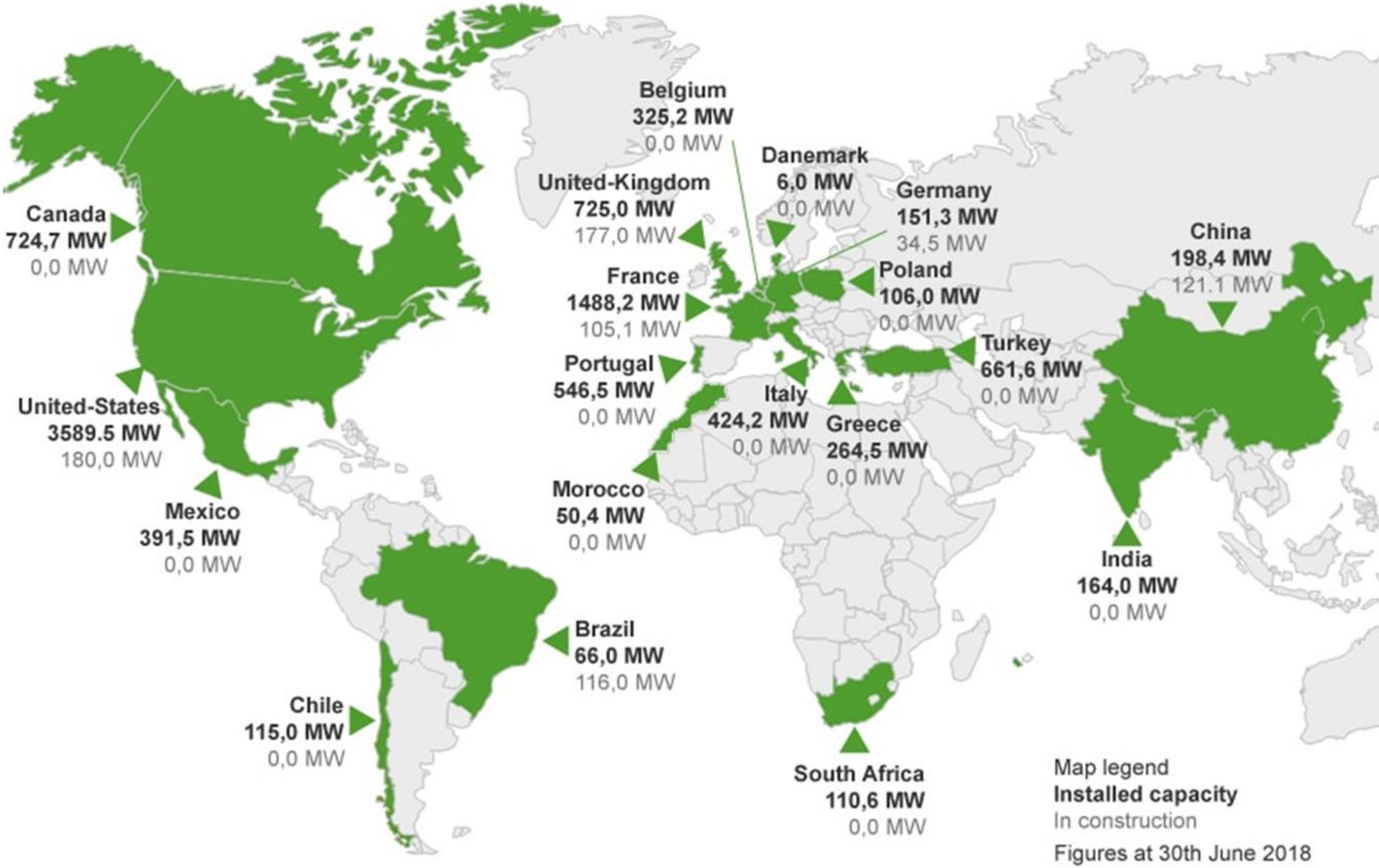
EDF Renewables: 10GW of installed wind turbine capacity (June 2018)

EDF Renewables Services: In-house provider of operation & maintenance services (working for internal and external markets)

EDF R&D: Innovation, collaboration, in-house development

# Onshore Wind Farms



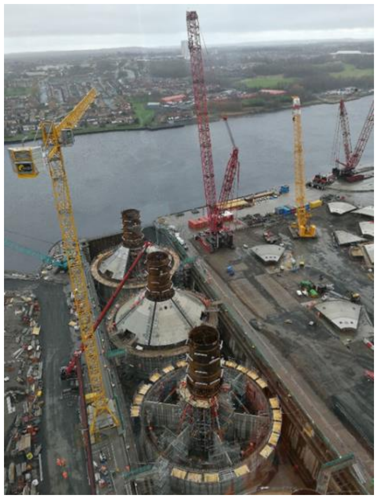

Ref: https://www.edf-renouvelables.com/en/project-development/onshore-wind/

# Offshore Wind Farms

Teesside 2013: 62MW, 27 turbines. Entirely developed, built and operated by EDF Renewables

Blyth 2017: 41MW, 5 turbines 8.3MW each, gravity base foundations



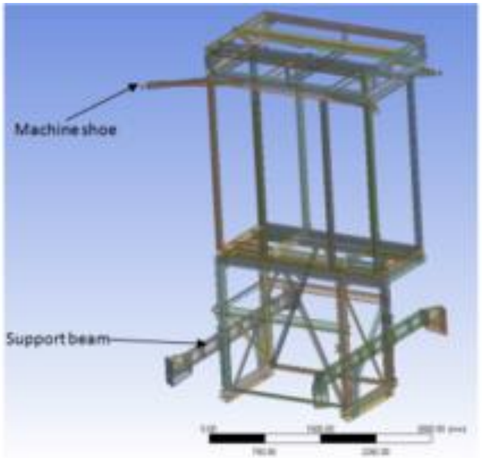
**France:** Three projects in development for 2022/23 generation


**UK:** NnG offshore wind farm in progress

- 15Km off Fife coast
- 450MW
- Jacket foundations
- 2022 generation

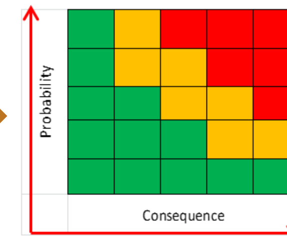
# Challenges

Design | Manufacturing Construction | In-Service





**Risk**
**Opportunity**
**Revenue**




**Diligence**
**Beyond design code**

**Procedures**
**Good practice**
**Quality**

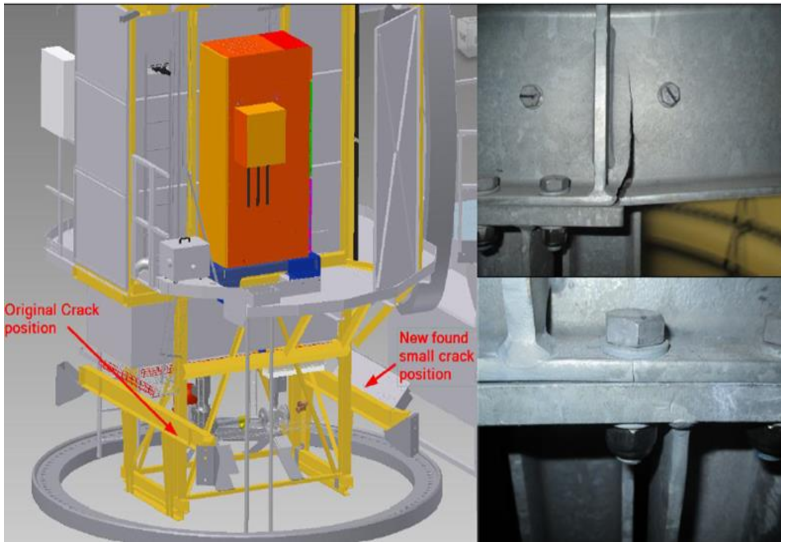
**Inspection:** method, value?
**Repairs:** method, durability?
**Actions:** timely, risk based
**Logistics:** fleet view, cost-effective?
**Durability:** meet expectations?

Through Life Design Assurance

# Example: Design Problem

- First EDF offshore wind farm, Commissioned in August 2013, 27; 2.3 MW turbines,
- Service availability agreement in place with the OEM for the operation and maintenance of the turbines with a target technical availability of 94.5% in year 1,
- Problem evident in November 2013, excessive vibration at the power and transformer modules inside the wind turbine tower on several turbines observed, cracked internal support beams (Transformer floor)

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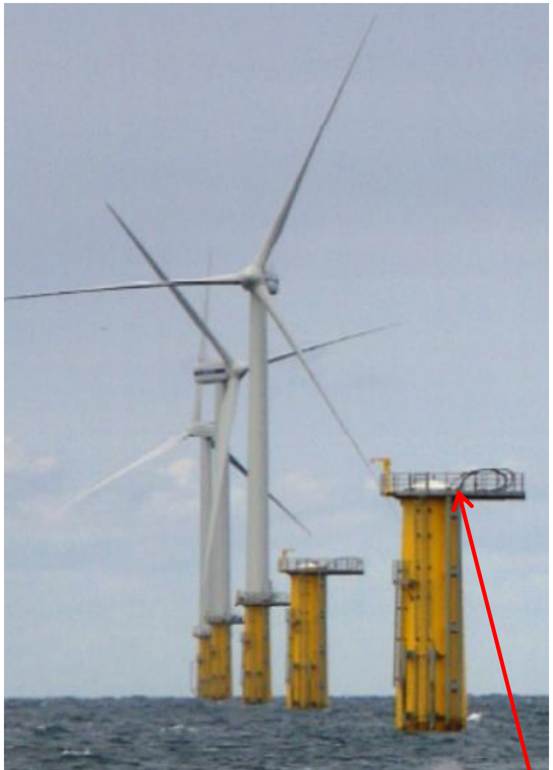
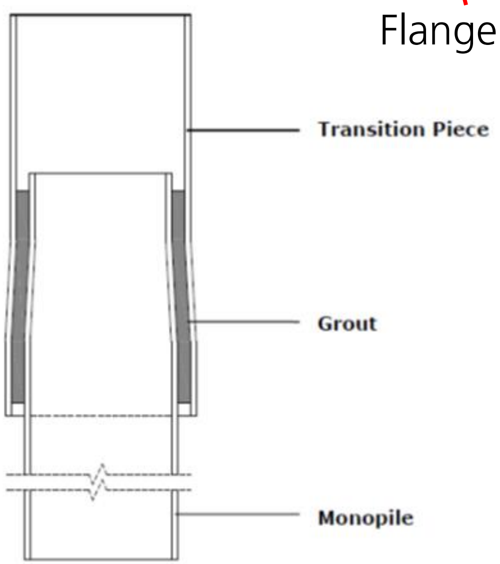
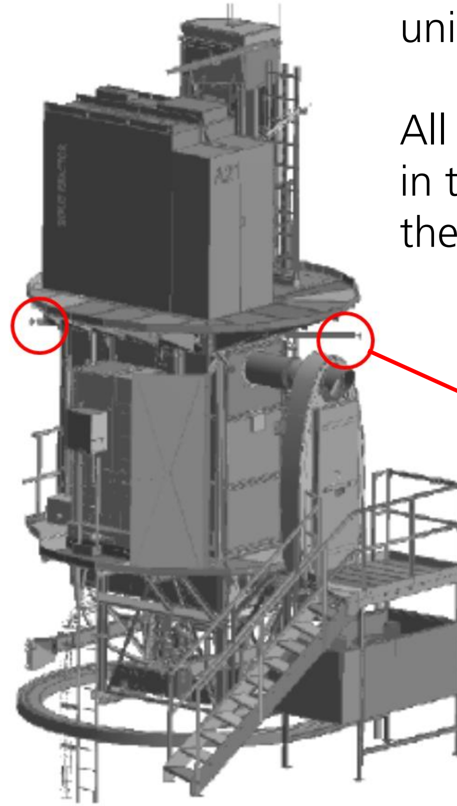


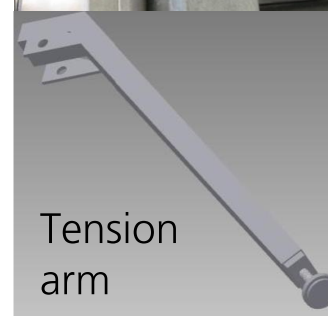



Flange



Internal platforms support the 690v/33Kv transformer, switchgear and the power units + ancillaries (12 tonnes)

All suspended on a skeletal frame, which is in turn supported of corbels attached to the inside of the tower



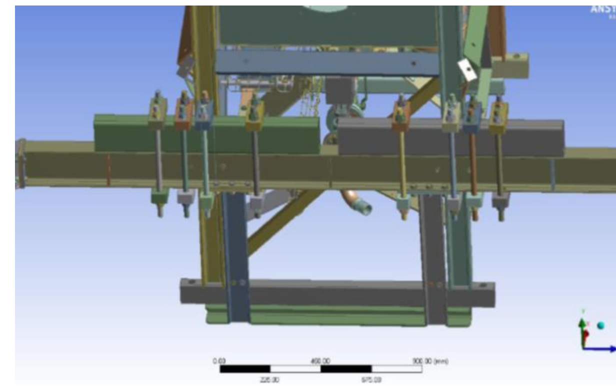

**Failure Sequence**

1. Tension arms (4) loosen
2. Subsequent reduction in natural frequency of the suspended platform, moves close to a harmonic; 1.6Hz
3. Excessive vibration leading to beam failure in a short time period (~ 2-4 months)

## Solution and points arising

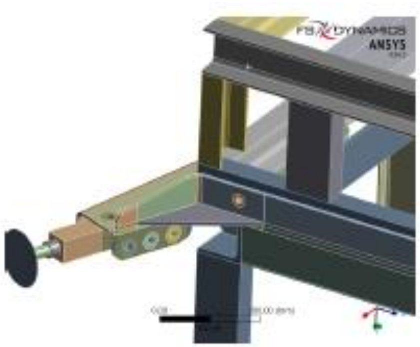
- Root cause; due to insufficient scrutiny at the design stage and poor installation

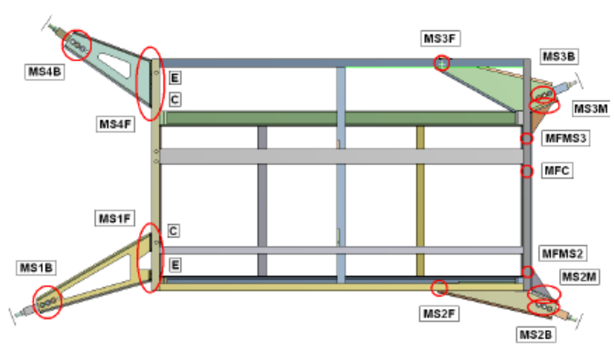
- Modified design; support beams relocated (mounted off tower flange), tension arm design strengthened……….still insufficient for 20 year design life

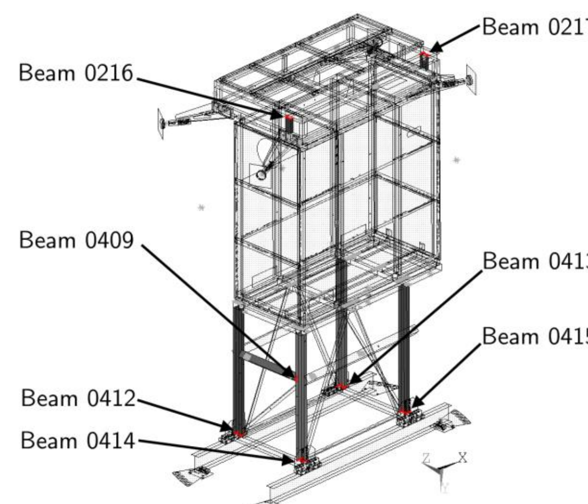


- During remediation period (~ 2 years)
  - NDT on all turbines
  - Load reduction (reducing vibration levels)
  - Design studies
  - Temporary (clamp) repairs
  - Sensors installed (alarm and turbine trip) **[SHM]**
  - Trial installation of new design for H&S compliance
  - Good support from the OEM

- New design
  - Fatigue ranking for future inspection
  - Spare tension arms and thorough install procedures





# Example: In-Service Problems

**2017 blade failure, ~ 9 years old**

Blade type prevalent across the fleet, 40m

RCA not wholly conclusive

Other major repairs on failed blade, not coincident with the failure. Inspections and repairs on the same type of blade across the fleet

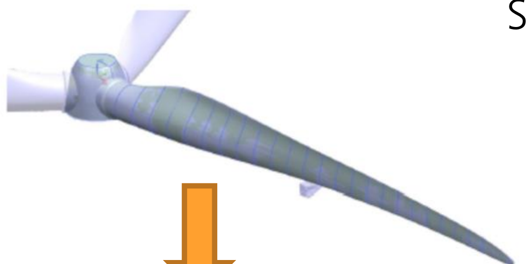

**2016 blade failure, ~ 20 years old**

~ 150m blade throw, old 2-bladed rotor design

RCA concluded failure from a prior repair location

Site location relatively close to housing, local roads

# Example: Converting a Problem to an Opportunity

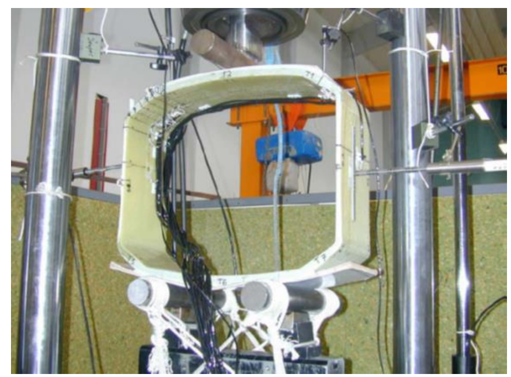


Two intact blades now available from the 2017 failure; one destined as a fleet spare, the other destined for R&D

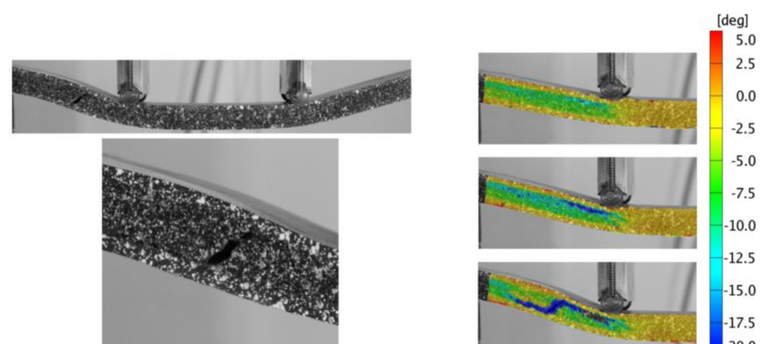
Same blade type on another wind farm laser scanned in 2016

Subsequent R&D plans developed

- Blade Modelling, Defect Tolerance, Damage Progression
- Inspection methods, trials
- Blade sectioning and sub-structure testing
- Inspection Protocols for Site



Ref: Previous work with Imperial College (Prof. Dear) and Riso Labs



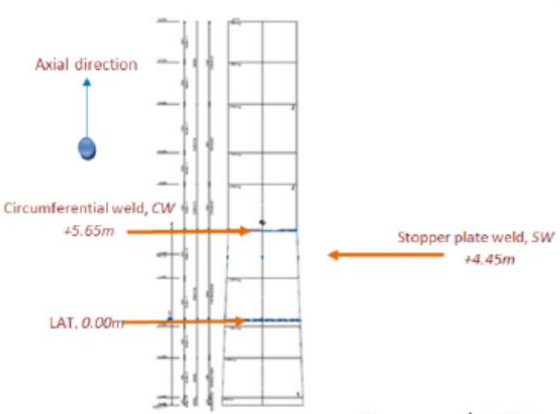
# Example: R&D planning for the foreseeable

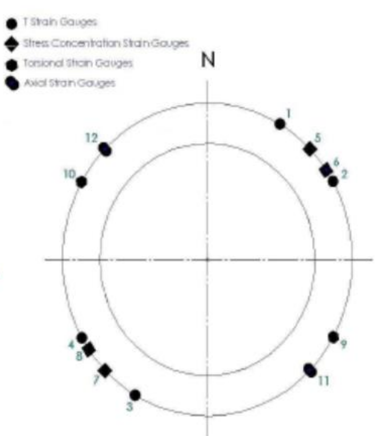
Ref: prior industry problems with monopile foundations and axial slip

Teesside offshore wind farm; two monopile foundations installed with SHM during construction.

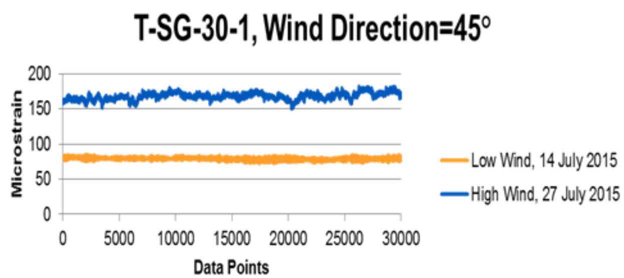
- Fatigue studies (other measurements ref corrosion, hydrogen, displacement etc)
- Offshore validation of structural response against structural model
- Confirmation that in-service measured foundation strain levels are much less than design basis. Clarifies location and extent for any foreseeable weld inspection required.

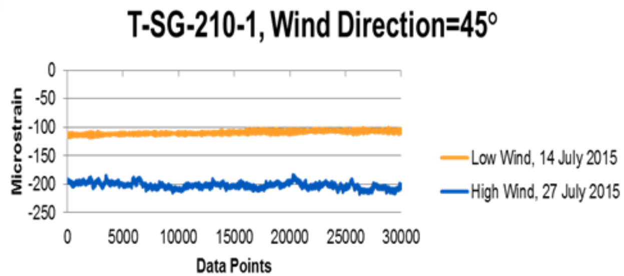
## Strain gauges

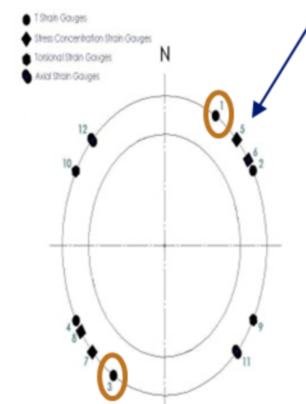



- Range: +/- 2000 microstrain
- 5 Hz low pass filter



- Facilitates current plans to mitigate risks arising from sub-optimal monopile cathodic protection performance (areas of under and over protection in the monopiles)

- Supports current Design Assurance activities on new offshore installations with jacket foundations at NnG

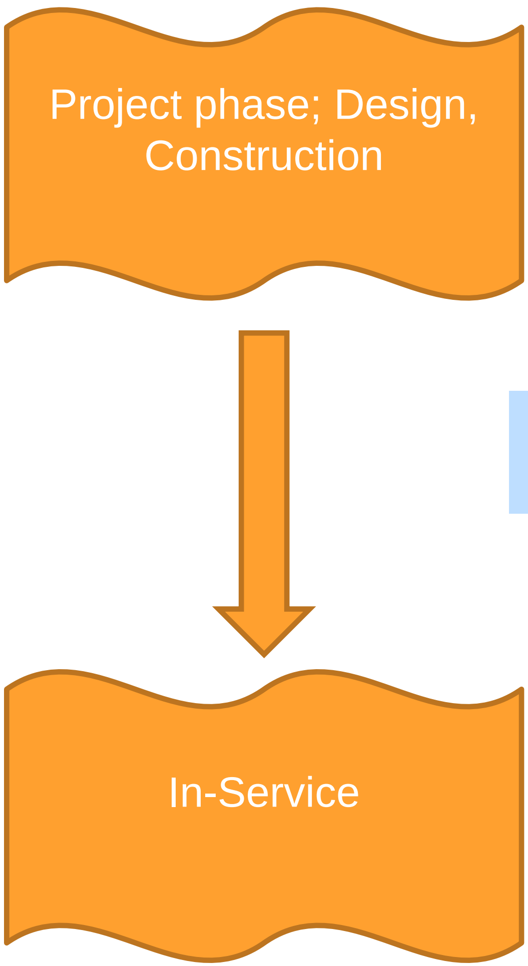
- Activities in plan for

  - Offshore foundation weld inspection and repair/mitigation methods

  - Use and deployment of robotic inspection vehicles

# What does the end user require?




- Design Assurance implemented from project inception through to handover to operations
- Inspection locations identified, priority ranked and accessible by design
- Manufacturing control/quality
- Thorough installation procedures

**A Good Handover of Project Documents and Outstanding Issues to the Operations Team**

- Process: Records of maintenance-inspection, repeatability, traceability. Leading to timely advice
- Inspection: Method, limits, appropriate validation
- Data: Analysis, interpretation, noise, quantity!
- Repairs: Durability, re-inspection intervals
- SHM: Practical and viable, supports risk re-evaluation, predictive?
- Logistics: Minimise cost to inspect, repair and maintain

# SHM and Inspection-NDT

1. Implementing a robust SHM approach should include the capability to predict remaining life or time to next inspection, based on validated methods/testing

2. SHM may be applied for short periods for data capture and development of a suitable predictive model

3. SHM may be relatively crude (Ref the example on the monitoring of the support frame tension arms and support beam cracking); aim is fit-for-purpose. Clarifying the message to the operator is paramount

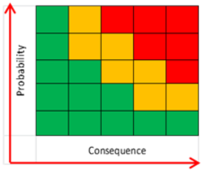
4. To accommodate the above SHM will invariably require a supporting model; for life prediction and validation against prior test data

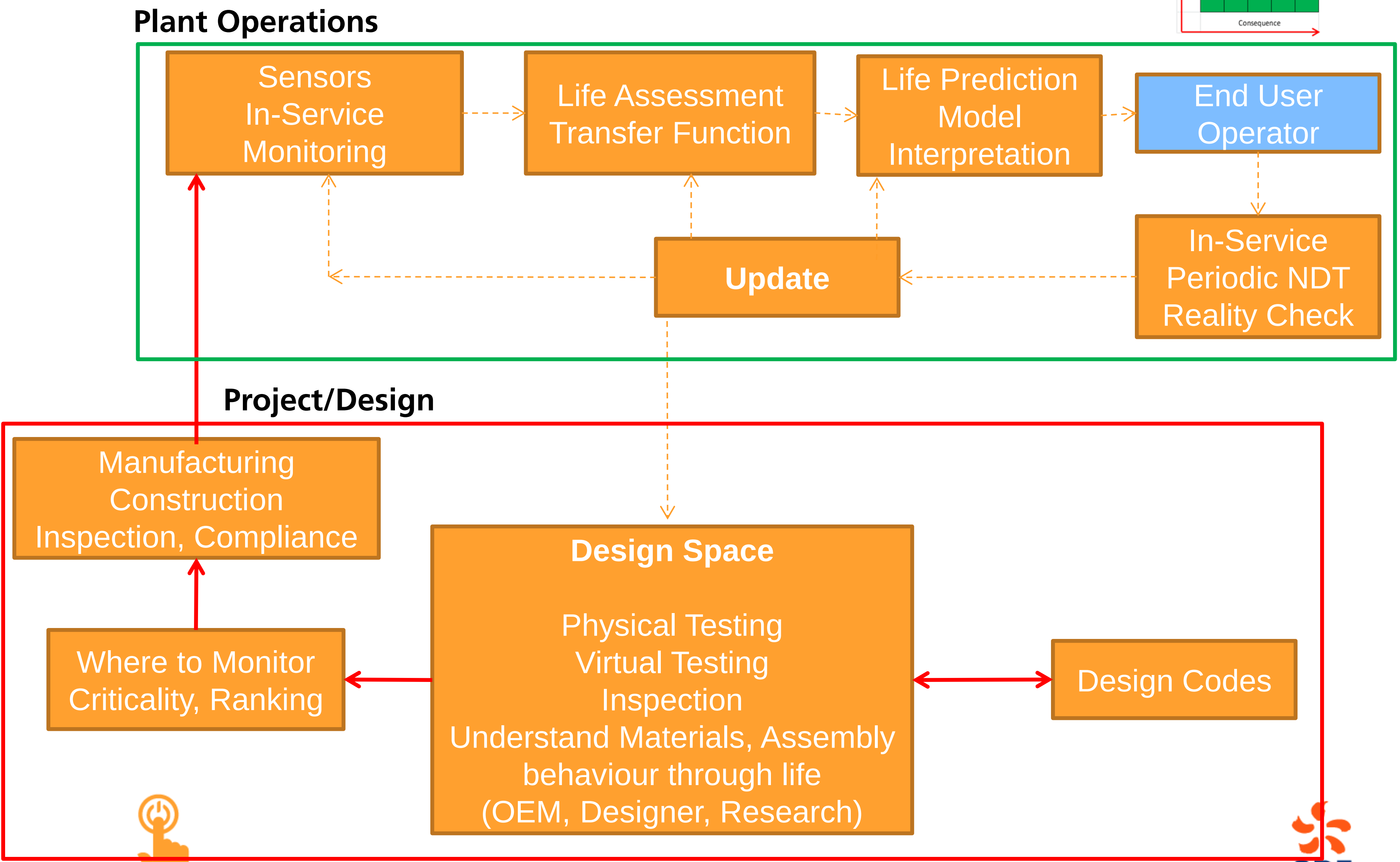
5. The target parameter life prediction purposes may not be directly measurable. A life assessment transfer function (LATF) of some description and suitable life prediction algorithms are required, likely composed of secondary variables that are measurable, including consideration of the rate of change (parameter(s)) in-service

6. SHM approaches can (and should) be deployed during both design/testing phases and for in-service monitoring. Use of SHM to support testing/simulation of components and sub-assemblies as part of the product design phase has great benefit.

7. NDT provides the necessary view on ‘do I believe the monitoring/prediction?’. This reality check is crucial

# SHM and Inspection-NDT



# End user must: Manage risk and set the priority

**Loading**
**(Force)**

- Load path through structure,
- Installation,
- Time and Rate,
- Transients, loading envelope
- Fault conditions,
- History and sequence,
- **Credible?**

**Inspection/Monitoring**
**(Reality)**

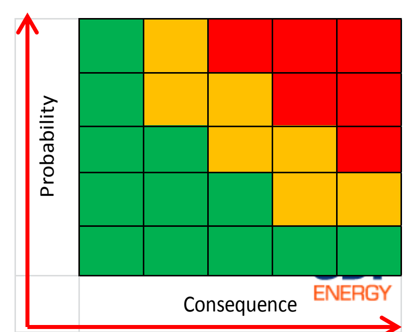
- Evidence of condition, NDT, metallurgy,
- Online monitoring,
- Observations from other plant,
- Big data, what's important?
- **Forewarning of failure, indicators?**

**Material Behaviour**
**(Resistance)**

- Properties,
- Time and Rate dependency,
- Environmental factors,
- Composition,
- Manufacturing process,
- Ageing in service,
- Predictive model,
- **Failure Mode(s)?**

- Seek a balanced view,
- Inform risk perception,
- Identify opportunities,
- Implement the right action for plant at the right time

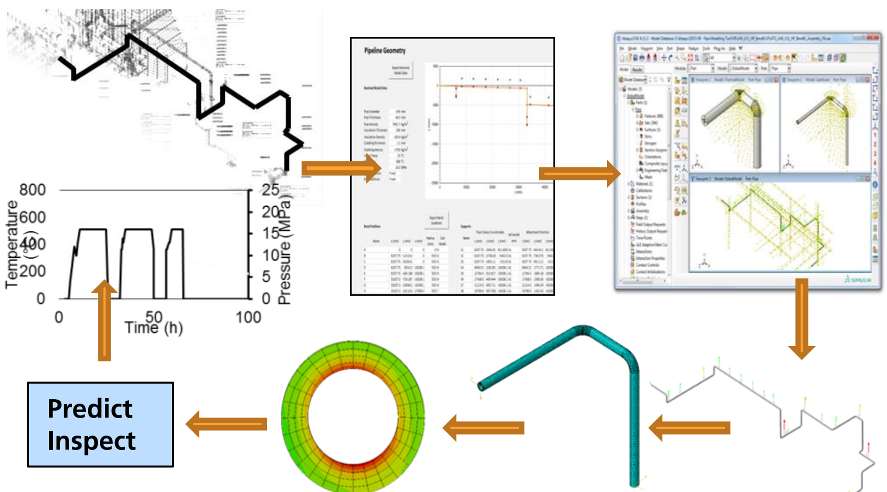
**Risk and Opportunity**



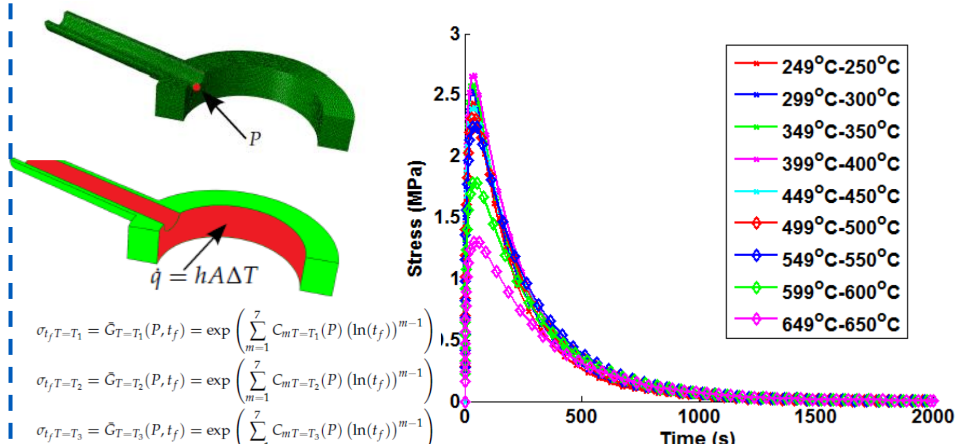

**Potential Barriers**
- Rarely do we have the full picture,
- Often, have to apply some level of subjective assessment,
- Lack of clarity tends to drive over conservative decisions (expensive),

# Examples of SHM: Inspection and Life Prediction from Thermal Generation




**Automated Process**




$$\sigma_{t_f T=T_1} = \bar{G}_{T=T_1}(P,t_f) = \exp\left(\sum_{m=1}^{7} C_{mT=T_1}(P)\left(\ln(t_f)\right)^{m-1}\right)$$

$$\sigma_{t_f T=T_2} = \bar{G}_{T=T_2}(P,t_f) = \exp\left(\sum_{m=1}^{7} C_{mT=T_2}(P)\left(\ln(t_f)\right)^{m-1}\right)$$

$$\sigma_{t_f T=T_3} = \bar{G}_{T=T_3}(P,t_f) = \exp\left(\sum_{m=1}^{7} C_{mT=T_3}(P)\left(\ln(t_f)\right)^{m-1}\right)$$

...

**Transfer Functions**

Both Approaches developed by long-standing collaboration with Universities and other like minded Utilities and research groups

- Utilise copious amounts of data
- Utilise more refined models of behaviour; absolute limits and rate of change
- Refine inspection scope
- Update models
- Online – Advise the Operator

# THANK YOU

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