Hydrodynamic Model Tests and Numerical Modelling: Exploring the Challenging Physics in Storm Waves

For ships and offshore structures in high and steep storm waves, nonlinear and complex physical phenomena will occur that are not properly modelled by consistent methods in standard industry tools. Advanced numerical modelling methods such as computational fluid dynamics (CFD) are under development, and promising advances are continuously being made.

However, the robust design load predictions needed by industry, still lack sufficiently well developed tools capable of handling all types of complex mechanisms, and simpler tools together with the appropriate corrections are still needed, although advanced studies are very useful sources of helpful additional information. The integrated use of model testing and various levels of numerical modelling is key to better understanding of the phenomena involved and to an efficient design process.

MARINTEK is involved in several developments of this sort, including JIP’s and special research projects.

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Wave impact and green water

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Design loads from wave impact in steep and breaking waves. The next step JIP.

There is growing interest in industry’s focus on estimating design loads from random wave slamming on marine structures in steep sea-states. This involves very complex hydrodynamic mechanisms, and is an area of continuous development. Standard industry methods cannot be applied, and model testing combined with empirical engineering tools are widely used. Better understanding of the underlying physics and of the challenges involved is essential.

MARINTEK has been in the lead of this development for the past 15 years, through numerous commissioned and joint industry research projects such as the Waveland and Wave Impact Loads JIP’s. A great deal of knowledge has been generated, and this has been implemented in improved methods and competence. These developments are still moving rapidly ahead, and new measurement techniques and equipment, combined with the accelerating field of advanced CFD tools offer new potential for elucidating complex mechanisms. The past few years have seen a focus on the extreme local slamming pressures exerted by breaking waves.

In order to implement this development in improved design tools, MARINTEK is proposing a new JIP. Model testing will continue to play an essential role in the project, while advanced theoretical and numerical models will provide very useful support. The design process is outlined in Figure 1. The total process is included, highlighting the fact that the end-product is the structural response.

The following elements are essential aspects of this work:
- Environmental description; selection of wave conditions
- Near-surface wave kinematics in near-breaking and breaking waves
- Impact load estimation: measurement techniques and numerical modelling
- Fluid-structure interaction; hydro-elasticity
- Scaling
- Rational, probabilistic selection of events; extreme values
- Final design load and response procedures

The scaling of small-scale slamming pressures is a particular challenge. For example, recent experiences with small air-bubbles have indicated a need to investigate this further; see an example below.

The extensive experience gained from earlier MARINTEK industry and development projects, and our co-operation with related projects at NTNU, will be a very useful basis for this work.

Recent examples from wave impact model tests

Among several recent wave-slamming model tests in MARINTEK’s Ocean Basin, an international cooperative project financed through the EU HYDRALAB IV programme was carried out together with several European universities, led by University College London. Various types of sensor...
for measuring wave-induced slamming pressures and forces on a vertical wall were benchmarked. High-speed video was another valuable tool. Samples from a high-speed video of the test are shown in Figure 2. The results of the study are being used to study the detailed slamming physics as well as to improve our measurement techniques in the laboratory.

Examples of the use of an improved, very stiff slamming force panel (which integrates the pressure over a small local area) are shown in Figure 3, which was obtained from a drop test. The device is characterized by a very high natural frequency (typically 5 KHz on model scale), which provides a much better picture of the underlying load signal, even with the very short load rise times that can occur in the most extreme cases. The examples also illustrate some challenging problems in slamming measurements, namely the presence of small air-bubbles, their influence on the measured signal, and related questions when upscaling to full scale. We can see that a bubble produces dynamic oscillations in the signal, and it is important to distinguish such effects from, for example, possible mechanical sensor oscillations (which are clearly more high-frequency phenomena in this case). The signals are also compared to classical 2D Wagner theory estimates, which show similar peak values while the difference in the tail is simply due to the retardation of the body (not included in the present calculations).

**Green water on FPSO**

An R&D co-operative project with Petrobras has recently investigated and improved engineering tools and the use of CFD methods to study green water and resulting impact loads on large FPSOs. The same problem has also been addressed as a part of a SINTEF software development project on Smoothed Particle Hydrodynamics (SPH) - SCORE. The phenomenon is characterized by complex, highly non-linear random events, combining ship motions with violent water-body interactions. This cannot be consistently modeled by standard industry methods, and model tests with empirical tuning of engineering methods, or advanced and very resource-intensive research methods, are needed. Three methodologies have been developed and investigated:

1) A fast, simplified engineering green-water prediction tool, Kinema3, has been developed and validated, based on key physical mechanisms combined with carefully implemented empirical knowledge from model test observations (Figure 4).

2) A double-domain one-way coupling has been established and validated combining Kinema3 with VOF (using the commercial StarCCM+ tool), by selecting events from the Kinema3 results as input to local CFD computations around the ship. The coupling accelerates the computation and facilitates extreme-value analyses of loads on any structure with complex geometry (Figure 5).

A similar coupling method has also been established using the Smoothed Particle Hydrodynamics (SPH) tool from SCORE instead of VOF; this has produced promising results. SPH is a Lagrangian (particle) method while VOF is an Eulerian (mesh) method. Both methods reproduce events reasonably well, while SPH offers some features that are particularly promising for future development.

3) Full VOF green-water simulations with a ship floating in waves have been studied using StarCCM+, which successfully reproduced events from model tests. However, this full-domain simulation is far more resource-intensive than the coupled methods described above, and further improvements are recommended for standard use.

EXWAVE JIP:
Slowly varying wave-induced forces and motions in high seas

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A new JIP is being started by MARINTEK in partnership with DNVGL, with the objective:
- Identify storm sea-state conditions and nonlinear wave-induced load mechanisms that may have led to extreme offsets and resulting line breakages.
- Recommend improved numerical modeling choices in practice and procedures that can be implemented in current simulation tools used by the industry.
- Formulate improved methods and procedures in industry practice for prediction of extreme wave-induced forces.
- Develop detailed recommendations and guidelines

Application areas include drilling vessels (MODUs) as well as floating production platforms such as FPSO’s and semisubmersibles, moored and/or DP controlled.

The topic is being paid greater attention after several line breakage incidents in storms in recent years, and there is a need for improvement. Overload has been identified as one critical factor, and the proper modelling of extreme wave-induced forces needs to be investigated. The JIP is planned for 2014-2016, and focuses on how to take into account the following physical phenomena in the hydrodynamic design process:
- Metocean conditions: wave groups, kinematics and currents
- Wave-current-structure interactions
- Large-amplitude-wave frequency relative motions

In current procedures and practice, the underlying theoretical modelling is based on a linear hydrodynamics formulation, and nonlinear phenomena in high seas are not always properly taken into account. Nor are wave-current interactions always taken into account, and simplified methods may be used. Model tests play an important role in highlighting and quantifying such effects, and although various empirical correction methods are often used in industry, these are often “ad hoc” types. There is thus a need to establish improved and widely accepted procedures and practice. More information about the JIP can be found in the JIP Proposal.

Examples of events and mechanisms that underline the need for such a development are shown below. An FPSO in high waves is shown in Figure 7, where large relative wave-vessel motions can be observed; this represents a clear deviation from the assumption of small motions of this sort. This may be one source of increased slowly-varying wave-drift forces, especially for wave frequencies around the spectral peak. One result of increased drift forces is extreme line-tension forces, as can be seen in Figure 8, where simulated and measured tensions for another FPSO in a 100-year wave are presented. Without corrected drift coefficients, the predicted forces are clearly lower than the measured forces, while the results obtained with tuned coefficients are much better.

The influence of wave-current interactions on wave-drift forces can be significant. The phenomenon is in principle well known in parts of the industry, although still not consistently taken into account in most standard industry tools. Model tests or simplified methods are often used; new industry software that includes this feature has been recently developed by MARINTEK (MULDIF). Global responses to impact loads in steep waves can also lead to increased slow-drift motions.

Viscous drift forces can be significant on column-based platforms in long and high waves. A number of model test examples from tests in storm waves have highlighted this, and empirical drift coefficients have been extracted showing a relatively large increase for long wave periods around 12s and higher.
It has been a common practice in design of tankers for transportation and floating storages of liquids to treat the liquid in a fully-filled tank as a rigid body (herein referred as “rigid” liquid) moving with the vessel and the effect of the liquid (forces and moments due to the liquid) on the vessel motion is included through the inertia of the “rigid” liquid as part of the vessel in calculating the vessel motion. This simple treatment makes it easy to include the inertia effect of the liquid. However, this simplification does not reflect the real physics well in many situations, which can result in significant error in predicting the motion of the vessel.

For example, consider a cylindrical (or spherical) tank full of liquid rotating about its axis of symmetry. If the liquid were considered as an ideal fluid, the rotating tank would not impose any moment on the liquid (no frictional tangential force) and the liquid would not move (rotate) with the tank. In return, the liquid would not exert any moment on the tank (thus the vessel, assuming the tank is fixed to the vessel). In reality, however, the liquid will move and rotate because of the tank imposes a moment on the liquid due to the friction between the liquid and the tank wall; in other words, the liquid exerts a moment on the tank (reaction). When the tank rotational velocity changes (acceleration or deceleration), the liquid motion changes. In this particular example, the velocity field and pressure fields are axisymmetric. The pressure on the tank wall does not contribute to the moment about the rotation axis since the moment arm is zero, the viscous friction is the only force to move the liquid. Due to the nature of viscous flow, the liquid motion is most likely limited to within the very thin boundary layer. It is very clear the liquid responds very differently to the change in the tank motion than the “rigid liquid”, thus exerting a very different moment (smaller) on the tank.

For tanks of different shapes other than the cylindrical (or spherical) shape, or cylindrical (or spherical) tank not rotating about the axisymmetric axis, the non-symmetric pressure distribution on the tank wall can contribute to the motion of the liquid, in addition to the friction force. Generally, the liquid will not move like a “rigid” body, and thus the force/moment on the flowing liquid by the moving tank would be different from the force/moment on the “rigid” liquid by the tank with the same motion. Or, in other words, the force/moment on the tank by the flowing liquid would be different from the force/moment by the “rigid” liquid according to Newton’s third law.

A preliminary study has been carried out to quantitatively examine the effect of the liquid movement on the moment on the tank. In the study, long cylindrical liquid tanks were considered and the tanks rotate about an axis parallel to their axes of symmetry (2D problem). Three types of the cross section shapes were used for the study: 1) circular, 2) square, and 3) rectangular. Assuming each of the tanks is sufficiently long, the flow in the direction of the symmetric axis is very small compared those in the other directions and can be ignored, resulting in a 2-dimensional problem. This problem is significantly relevant to the roll motion of a ship carrying liquid (such as crude oil, liquefied natural gas, and other liquids).

Numerical simulations of the flow inside a tank were used for the study. Viscous flow model (2-D Navier-Stokes equations) was used for the liquid motion. A CFD approach with a software called COMSOL Multiphasic (a general solver for partial...
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differential equations based on finite element method) was used to solve and simulate the flow inside the tank for all the study cases. The open-source software, OpenFoam, was also used for a limited number of study cases as spot-checks to verify the COMSOL results. Once the flow was solved and the pressure and the shear stress on the tank wall were obtained, the moment on the tank due to the liquid was calculated by integrating the pressure and the shear stress over the tank wall surfaces. An alternative approach based on the momentum theory was also used to obtain the moment which was compared with the moment using the direct surface integration. A good agreement indicates a good accuracy of the flow solution.

Figures 1-3 show the pressure field of the liquid in the tanks with circular, square and rectangular cross sections of a same area, respectively, viewed in the tank-fixed coordinate system at some time instants when the tank motion has reached a steady state. The tanks oscillate about a point some distance (5m for the circular and square tanks and 6m for the rectangular tank) from their geometry center with a rotation angle amplitude \( \Theta_o = 45 \) degrees and the oscillation frequency \( \omega = 1.7 \) rad/s. The gravitational force (hydrostatic pressure) was included in the simulations. The fluid used for the study is SAE 30 oil.

To assess the significance of the effect of the liquid motion on the tank, a so-called equivalent moment of inertia ratio was introduced,

\[
\varepsilon = \frac{M_{lq}}{M_{rl}} = \frac{I_{lq}}{I_{rl}}
\]

where \( M_{lq} \) is the amplitude of the moment exerted on the tank by the liquid and \( M_{rl} \) is the amplitude of the moment exerted on the tank by the liquid if the liquid is treated as rigid rotating with the tank. \( J_{lq} \) is the moment of inertia of the “rigid” liquid and \( J_{rl} \) is defined as the equivalent moment of inertia,

\[
J_{rl} = \frac{M_{rl}}{\omega^2 \Theta_o}
\]

\( \varepsilon \) is a good measurement of the effect of the liquid movement on the moment on the tank by the liquid. If \( \varepsilon = 1 \), the liquid behaves like a rigid body (“rigid” liquid). Otherwise, the liquid behaves differently from the “rigid” liquid. The further the ratio \( \varepsilon \) is away from 1, the stronger the effect of the liquid movement. In the very special case of circular cylindrical (or a spherical) tank rotating about its geometric axis, \( \varepsilon \) would be very small (close to zero). In the limit of ideal fluid (no friction), \( \varepsilon = 0 \).

The study examines the influence of a few parameters on \( \varepsilon \). The parameters include 1) separation distance of the tank geometry center to the rotation center \( H \); 2) oscillation amplitude \( \Theta_o \); 3) oscillation frequency \( \omega \); and 4) length-height ratio of the rectangle Ax/Ay in the case of the rectangular tank.

It is interesting to further investigate the linearity of the system with respect to the rotation frequency in cases the tank rotates with multiple frequencies. The linearity is also important for the superposition principle to be used to allow a proposed simple way of including the effect of the liquid movement in the tank in calculating the vessel motion in random seas.

Based on the study results, the following conclusions are drawn:

1 - The movement of the liquid inside a tank relative to the tank reduces the inertia of the tank. The equivalent moment of inertia of the flowing liquid can be significantly smaller than that of the “rigid” liquid. As the separation \( H \) increases, \( \varepsilon \) becomes closer to 100%, indicating the liquid behaving more like the rigid body. As examples, Figure 4 and Figure 5 show the effect of \( H \) for the circular and square tanks, and for the rectangular tank, respectively. It is very important to include the effect of liquid motion in the vessel motion calculation when \( H \) is small.

2 - For the rectangular tank, the equivalent moment of inertia ratio \( \varepsilon \) strongly depends on the length-height ratio of the cross section. \( \varepsilon \) increases with \( H \), approaching 100% asymptotically, as shown in Figure 6.

3 - The contribution from the viscous shear stress to the moment on the tank is very small compared to the contribution from the dynamic pressure in the fluid, except in the...
Wind Loads and the Wind Field around Offshore Structures

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Our expertise in the evaluation of wind loads on offshore structures was presented in an earlier MARINTEK REVIEW article [1]. After two years of intensive research and development, our CFD approach has been validated and is now capable of predicting the wind field around a complex offshore structure, rapidly, efficiently and reliably.

Global wind loads are of great importance in the design of offshore structures, especially their positioning system – whether moorings or dynamic positioning system, is being designed to withstand extreme events. By combining wind tunnel measurements and computational fluid dynamics (CFD) calculations, MARINTEK’s approach [2] allows uncertainties to be quantified, and increases the level of confidence in the estimated loads. On the one hand, CFD is particularly suitable for providing a detailed description of pressure fields and flow conditions, and thus insight into physical phenomena, while on the other, advanced model testing is a valuable way in which to validate the solvers, the numerical settings, and results.

After two years of intensive research in collaboration with Statoil ASA, MARINTEK has now developed and validated a methodology that efficiently and reliably describes the wind field around a large complex structure. Our analyses meet the offshore industry’s need for accurate wind field prediction, for example for (1) gas dispersion analyses, (2) determination of free-fall lifeboat operability in strong winds, (3) interpretation of offshore wind measurements and post-hoc calibration of metocean models, (4) analyses of critical marine operations, such as tandem offloading of cargo or (5) helicopter landing.

In improving our methods, we focused on three aspects in particular: meshing techniques, Atmospheric Boundary Layer (ABL)


Figure 1. The meshing technique applied in MARINTEK’s methodology does not leave out any relevant detail of the geometry, avoiding uncertainties due to geometric simplification.

First, efficient techniques that permitted high-fidelity meshing of very large structures were developed. Figure 1 shows the mesh of a 250 m-long FPSO, including components in a wide range of shapes and size. One important aspect of the method is that no relevant detail is left out of the CFD model, thus avoiding uncertainty resulting from geometric simplification, which is generally employed in wind tunnel tests and some CFD methods.

Secondly, close attention was paid to the modelling of the Atmospheric Boundary Layer (ABL), often referred to as “wind profile”. Methods were used that ensured the propagation and conservation of the properties of the ABL, including turbulence, throughout the virtual wind tunnel [3]. Those methods were adapted to take the specificities of the wind profiles used in the offshore industry into account.

The third focus was on validation. Particle Image Velocimetry (PIV) experiments were performed in a wind tunnel in order to obtain experimentally a high-resolution description of the wind field around an FPSO. Results were compared to our full-scale CFD calculations (Figure 2). Those results, reviewed in collaboration with a world-leading research institution on wind flow predictions, led to the conclusion that the methodology has been validated and can be regarded as being reliable for wind field analysis.

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MARINTEK’s method, which combines CFD methods and model testing, significantly reduces uncertainty in estimates of wind load by considering all the geometric details of the offshore structure, by carefully modelling the offshore wind profile, and by avoiding scale effects through the use of full-scale simulations. This approach has also shown itself to be flexible, and provides a very detailed understanding of the wind field around a complex and realistic structure.

Figure 2. The wind field around an FSPO (here at the free-fall lifeboat’s drop area) was measured by means of PIV and compared to CFD simulations. The incoming wind profile is an offshore Atmospheric Boundary Layer. High-resolution visualization allows deep understanding of the wind field.

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special case of the circular tank (or a spherical tank in 3D) rotating about its axis of symmetry. In this special case, the only contribution to the moment comes from the viscous shear stress. However, the magnitude of the moment on the liquid by the tank is much smaller than that if the liquid was a rigid body for a same rotational motion of the tank.

4 - The dependency of $\varepsilon$ on $\theta_0$ and $\omega$ is very weak.

5 - The preliminary investigation indicates that the superposition principle may be applied for cases with the multiple-frequency tank motions.

Based on the weak dependency of $\varepsilon$ on the rotation amplitude and frequency, and the validity of the superposition (Conclusions 4 and 5), a simple method to include the effect of the liquid movement in a fully-filled tank in the frequency-domain calculation of the motions of a ship/vessel has been proposed. In the method, the equivalent moment of inertia ratio can be pre-determined for a tank. In the ship motion calculation, the equivalent moment of inertia of the liquid is added to the moment of inertia of the ship in a similar way the contribution from other rigid components is included.

More details of the study can be found in the references list below.

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Fuwei Zhang of MARINTEK USA performed the simulations using COMSOL Multiphysics and the results were used to draw the conclusions. Haidong Lu of MARINTEK USA performed the simulations using OpenFoam for spot-checking of the COMSOL results for the circular and square tanks.

References

Joint Industry Project - Safe and Cost-Effective Operation of Flexible Pipes

Improved Reliability in the Operation of Flexible Pipes

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A flexible pipe for offshore transport of fluids or gases incorporates a complex multi-layer pipe wall. This structure provides greater flexibility than conventional steel pipes. Most flexible pipes are either flowlines (laid on the seabed) or risers (rising from the seabed to a structure on the surface). The need for flexibility is largely in order to accommodate the motions of the floating vessel connected to the top of the risers. Other reasons include seabed irregularity, strict routing requirements and the ability to store long lengths of pipe on reels, which can be an advantage during installation.

Flexible pipes are vital to subsea development projects and have been in use in Norwegian oil and gas production facilities since 1986. To qualify such technology for North Sea applications, the FPS2000 research programme was carried out by SINTEF in 1987-1992, with financial support from oil companies and the Research Council of Norway. The effort was motivated by the need to reduce the cost of future field developments, facing both the shortcomings of fixed platform technology available at that time and a desire to ensure greater financial robustness towards movements in the price of oil.

Since 1990 there has been an ever wider use of floating ves-

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sels (floating platforms, FPSOs, etc.) in the Norwegian sector, and the number of flexible risers in service rose to more than 300 by 2013. Many flexible pipes are operating under very demanding conditions, at high pressures and temperatures, and with large fluctuations in operating parameters and high dynamic loading. However, a number of incidents with flexible risers have led to risers having to be replaced. A significant proportion of the flexible risers in use in the Norwegian offshore sector have not yet met the design service life either due to replacements or not yet reached the design service life (Petroleum Safety Authority Norway; “Un-bonded Flexible Risers – Recent Field Experience and Actions for Increased Robustness”, 4Subsea report, 31-12-2013).

As a combined effort between MARINTEK, NTNU and 4Subsea AS the Joint Industry Project “Safe and Cost Effective Operation of Flexible Pipes” was established in 2011. The project aimed to improve reliability in the operation of flexible pipes.

A key project delivery is the Handbook on Design and Operation of Flexible Pipes, which was first issued by the FPS2000 project in 1992 when the flexible pipe era was still in its infancy. The new JIP (2011) adopted a practical approach based on experience and guidance related to pipe repair, lifetime assessment, integrity management and the application of reliability methodologies. Important knowledge regarding the evaluation of the condition and capacity of flexible pipes after some time in service has been documented.

Specifically, more insight has been gained into the fatigue properties of the tensile steel armour of used pipes through the testing and surface evaluation of corroded armour wires. The internal environment inside the pipe wall (annulus) and corresponding potential corrosion issues have been described. Finally, numerical methods and tools for analysing load carrying components in the pipe wall, also taking corrosion damage into account, have been significantly improved since 1992.

The revised handbook, Handbook 2014 contains the following parts:

**Part A: Flexible Systems**
- Flexible pipe systems
- Flexible pipe properties and materials
- Failure modes

**Part B: Design and Analysis Tools**
- Design analysis
- Risk analysis methodology
- Reliability methods
- Annulus environment and corrosion
- Test methods

**Part C: Operation**
- Integrity management
- Lifetime assessment
- Repair methods

**Part D: Case Study**
- Small-scale fatigue testing of tensile armour wires from sweet service flexible risers taken out of service after several years in operation
- Characterization of surfaces in relation to fatigue properties of corroded tensile armour wires from flexible risers taken out of service
- Demonstration of tools for assessing the integrity of a flexible pipe cross-section in the event of corrosion damage to tensile armour wires
- Demonstration of lifetime assessment and integrity management processes for a flexible riser
- Application of reliability methods for integrity assessment of a flexible riser
- Lateral buckling analysis of flexible riser tension armour wire

The aim of the Handbook is to provide background and guidance regarding methods for the design and operation of flexible risers. Rules and specifications, such as API/ISO, which set out requirements with regard to design, materials, etc., provide very limited background and guidance on methods. The Handbook will complement available API/ISO documents. The 2014 Handbook also aims to continue the role played by the Handbook 1992 as a text for education and experience delivery to new generations of flexible pipe engineers.

The JIP Safe and Cost Effective Operation of Flexible Pipes (2011-2014) has been sponsored by the oil companies Lundin, Maersk Oil, ConocoPhillips, Dong Energy, Shell, Talisman Energy and ExxonMobil, and will be finalized early in 2014.
The significant potential to increase expected recovery rates from mature fields in addition to tie-in of near-field discoveries make the case for extending the life of ageing production facilities an important proposition. Production facility life extension is a major business case. The complexity of the facilities, harsh environment, progression of known and new degradation and failure mechanisms all make the efficient gathering, analysis, prognosis and presentation of the required decision support information exceedingly challenging. MARINTEK is host for a joint industry project - Production Facility Life Extension - to be launched in 2014 by the Consortium for Petroleum Production Facilities, CPPF. This comprises 6 R&D partners, namely MARINTEK, SINTEF, IFE, IRIS, NTNU and UiS working together with the oil and gas industry.

The vision for the project is to improve the lifetime and value contribution of petroleum facilities while assuring safety for people, environment and assets. At any given time, we should be able to look at any facility and immediately understand 1) its current and future state, 2) remaining useful life, and 3) its top high risks and uncertainties. This will require highly innovative R&D since it is not currently possible to do with a high degree of confidence. We will therefore create a step change in industry’s ability to predict. Hence life extension decisions can be better managed through improved asset integrity, prediction and reduced uncertainty, thus improving safety and value potential.

Many oil and gas platforms are operating at or beyond their original design life. There remains conservatism and uncertainty in the ageing models used to specify design life. The economic value in supporting optimized life extension decisions is significant in assuring safe operation of the facility for a longer period, i.e. to permit extension of the production period from the current design life to the safe permissible limit. The assessment of risk and contribution of human factors and organizational resilience are integral parts of this evaluation. We therefore increase confidence in the ability to extend operation of the facility within the critical state and avoid incidents.

The project will deliver a holistic system to support short and long term decision making for life extension optimization. It shall facilitate presentation and visualization of aggregated assessment of a production facility’s current and forecast condition, remaining useful life, risk, and probability of future incidents. It shall permit investigation at all levels in the facility hierarchy (i.e. group of production systems, system, subsystem or component level) for identification of contributors to increased degradation or risk. Probability evaluation and distribution models will support selection from alternative actions for life extension. The system must complement existing company processes.

This R&D will be executed on real company provided cases where data may be fully or partly available. Examples of these could be for instance a water injection platform including its equipment, systems and flowlines, or a subsea development with Floating Production Unit. The R&D will start on a more limited critical system requiring life extension. Following analysis of critical decision processes for life extension, an integrated iterative concurrent engineering approach will be used for ‘smart’ CAPTURE & MODELLING of the required data. The resulting data-driven models for DEGRADATION & RUL (Remaining Useful Life) and their PREDICTION will generate alternative courses of action for life extension of the production facilities, based on the industry cases provided.

By INTEGRATING classification of the RISK & RESILIENCE impact for each alternative, the final AGGREGATE & VISUAL-
IZE step will provide the basis (with underlying models & data) for optimal DECISION making under uncertain conditions, fully supported by dynamic risk evaluation.

The predictions shall be based on a clear understanding of the key factors that will impact the integrity of production facilities. Developed together with industry, it shall respond to the industry statement: “We need to be predictive – we need to be able to predict anything, anytime, everything. I want a model, system that can find both what I’m looking for and what I don’t know that I’m looking for”.

The JIP shall deliver successive generations of the system as its maturity develops from ‘Technical Readiness Level 0’ onwards, representing progression from an initial concept to a tested solution.

The 6 R&D partners each bring internationally leading competence to this JIP, which they have developed from work in multiple industry sectors in addition to Oil & Gas. The scientific depth from our 2 Universities coupled to the innovative vision of our 4 R&D Institutes complement industry to form the innovative “R&D – University – Industry” triangle.

This case-based R&D will be 100% steered and governed by industry. The R&D partners working jointly with industry create a collaborative environment which can be steered to generate world class innovation relevant to life extension. Concurrent engineering and new collaborative approaches will be adopted for enhanced efficiency.