ENERGY MATTERS

BMT Group

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MESSAGE FROM THE MANAGING DIRECTOR, ENERGY

Risk is always inherent in engineering design and operational decisions but never more so in a cost competitive environment. With challenging energy markets, commercial decisions are under the scrutiny of investors and stakeholders, whilst operational safety must be maintained.

Understanding the level of risk at the various stages of development through to the final operation is paramount to maintaining costs at acceptable levels while ensuring safety standards are upheld. Achieving a commercially viable venture requires a thorough knowledge of not only the operational environmental conditions but also the integrity and behaviour of the asset throughout its lifespan.

A combination of good quality data generated from accurate numerical modelling techniques and measurements enables consultants to use their expertise and regional knowledge to provide an assessment or indication of risk to support a development or operation.

From the impact of geotechnical hazards on onshore pipelines to complex operations offshore, levels of risk needs to be considered over a wide range of elements and often requires collaboration with partners who have access to niche expertise.

At BMT, we strive to understand all elements related to commercial, environmental and operational risk by using a range of in-house data, software, instrumentation and knowledge, also recognising the benefits of working in collaboration with industry partners to provide a fully integrated risk assessment to our customers.

In this edition of Energy Matters, we have focused on the products and solutions that BMT offers to help assess the level of risk and the benefit that this offers in terms of safety and cost control.

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BMT LAUNCHES ICE CHARTING CAPABILITY

The risks associated with sea-ice hazards on shipping or offshore infrastructure developments can have significant impact on the safety and cost associated with offshore operations.

Combining extensive weather forecasting expertise with ice charting capability, BMT is pleased to announce the launch of a unique service offering, providing enhanced and cost effective services to customers globally.

Jean-Paul Lindeboom, Director of Metocean Weather Forecasting at BMT says: “This combined capability under one roof is unique to the market. More and more of our clients are looking at these new, harsher environments, therefore having both a comprehensive understanding of the weather and the ice regime makes sense as a complete package, providing cost efficiencies and a more progressive service for our customers.”

As part of this new capability, a number of BMT’s key senior meteorologists have been working with the Danish Meteorological Institute to gain a better understanding of ice charting.

BMT’s Mark van der Putte who took part in the initiative comments: “This work has allowed us to better understand the ice regime, i.e. how ice builds up, how it moves and reacts and how it evolves during the season. Interpreting satellite images is also a key requirement for delivering an effective output. The ice build-up and movement is very dependent on the weather therefore our extensive meteorological knowledge and experience will help us to further improve the service we provide.”

For the past 18 years, BMT has provided a wide range of services aimed at reducing the risks involved with offshore design and operations. Its expertise in the field of metocean modelling, meteorology and weather forecasting as well as remote sensing data has been utilised for projects in areas such as Yamal, the Baltic Sea, the Caspian Sea and the Sakhalin sea area.

“This combined capability under one roof is unique to the market.”

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Director Metocean Weather Forecasting

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HAPPY LANDINGS

HELICOPTER SAFETY ON THE NEW FRONTIERS OF THE OFFSHORE INDUSTRY

Maintaining existing assets and delivering operational efficiencies through a more thorough understanding of the limiting environment around the platform will help the offshore industry meet the challenges of getting people to and from work safely.

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"Maintenance of Helideck Monitoring Systems on platforms should not be overlooked, they form a key input to safe operations and should be maintained on a regular basis to ensure that the accuracy of sensors and quality of the data is within the required thresholds.

BMT recognizes the importance of after-sales service support to ensure the integrity of the long-term data that is used in many of the key decisions during operations."

***Jordan Krumm**,*
Service & Upgrade Sales Manager

BMT has extensive experience in offshore helicopter operations and guidance, having provided various services to the offshore industry for over two decades. BMT carried out several important helicopter operations research projects for regulatory bodies such as the UK Civil Aviation Authority (CAA) and the Health and Safety Executive (HSE). Lessons learnt from these research projects were used to compile key industry regulatory documents such as the CAA Helideck Design Considerations – Environmental Effects and CAP 437.

From the industry experience gained from hundreds of projects, BMT has provided services to the offshore Oil & Gas industry to understand:

- Impact from turbulence, unburnt hydrocarbons and hot emissions on helicopter operations through computational fluid dynamics (CFD) modelling for design and to achieve CAP 437 compliance
- The optimal location and design of the helideck through wind tunnel testing and analysis of the wind flow over the structure for varying wind conditions
- Risks from wind, gusts, visibility and lighting through aviation forecast services to help enable safe helicopter operations and minimise unnecessary weather related downtime
- Influence of metocean and helideck motion characteristics through customised Integrated Marine Monitoring Systems (IMMS) to ensure compliance with CAP 437 and to assist in assessing the feasibility of landing a helicopter

The information from these specialist services in CFD Modelling, Weather Forecasting and IMMS are unified and presented through BMT's new and powerful product Data Exploration and Analytics Platform for Actionable Insights (DEAP-AI).

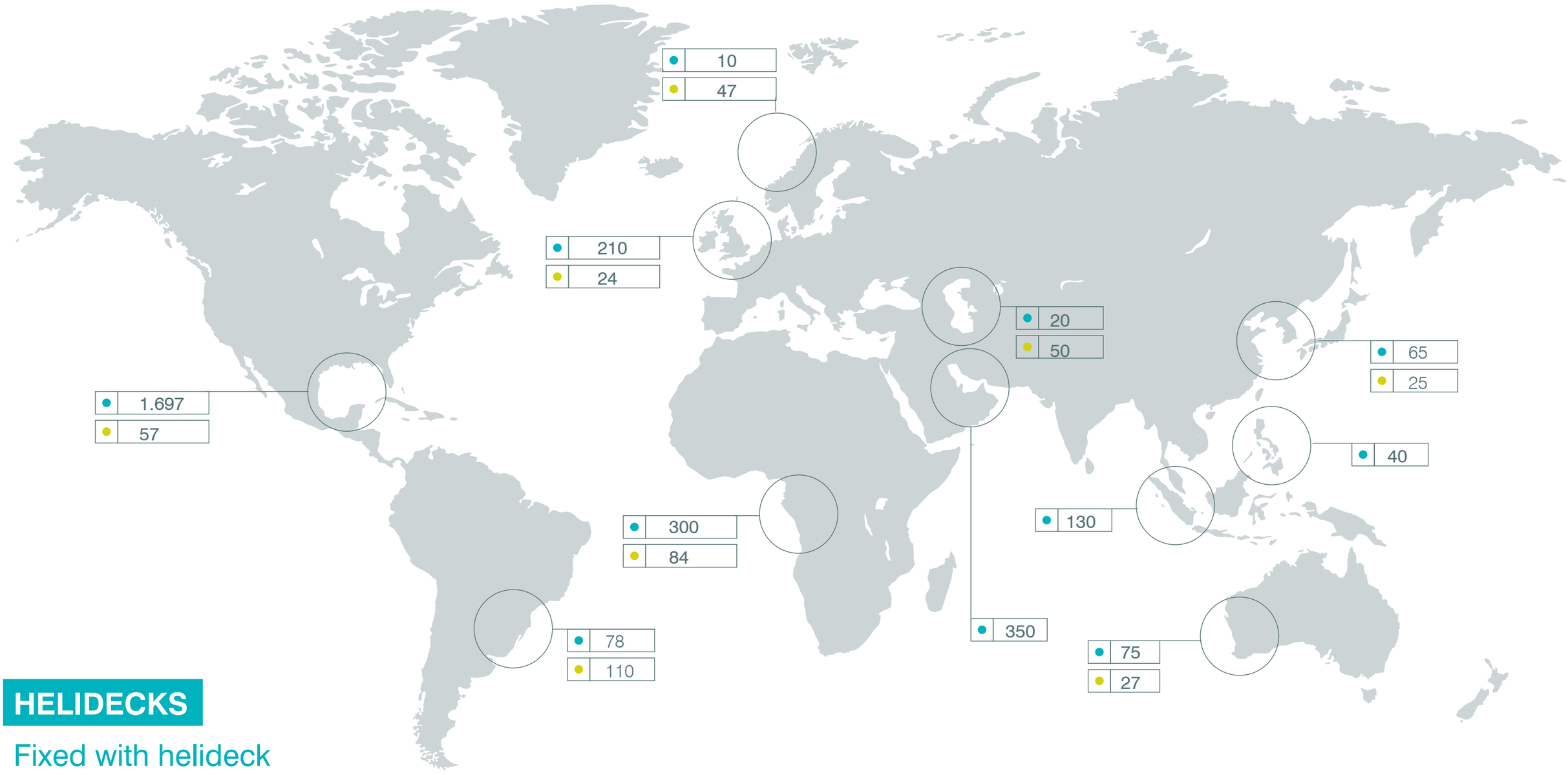
The platform provides a cost-effective solution to ensure helipad downtime is minimised whilst enhancing the industry's approach to safety in helicopter operations. DEAP-AI provides custom dashboards and allows users to delve into historical data as well as continuously monitor information as it is captured in real-time.

BMT's approach to real-time helipad operations through DEAP-AI assists our clients in making more informed and faster decisions, allowing ever more efficient use of helicopters and crews whilst ensuring safety remains a top priority.

OFFSHORE MARKET

“There is no one-size-fits-all for safe helicopter operations. Different environments are hostile in different ways and safety will depend on a host of factors, from the physical helipad itself to the abilities of the crew operating it.”

***Alex Knight**, Managing Director of the Helideck Certification Agency (HCA).*

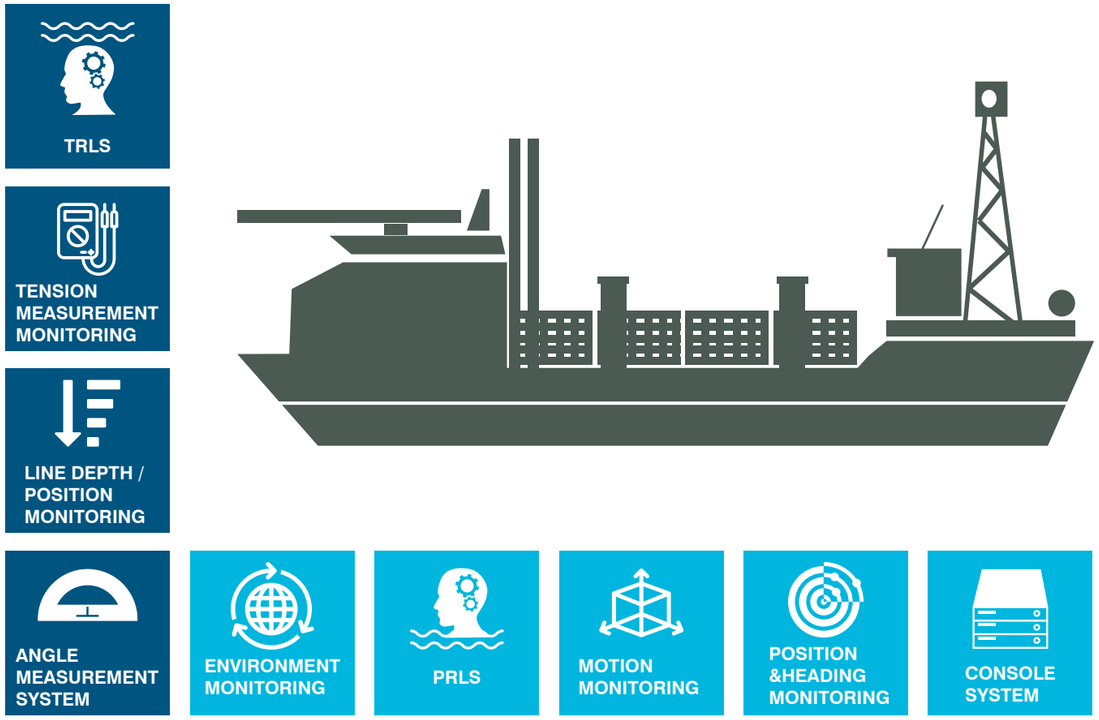


HELIDECKS

Fixed with helideck
Floating Production with helideck

Estimate of number of operational helidecks globally (Source HCA)

BMT POSITION AND TENSION RESPONSE LEARNING SYSTEMS



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"A reliable cost-effective method of managing the integrity of the mooring lines is sought after by the industry to improve upon existing systems and practices."

Maintaining a floating platform on station is critical to the overall safety and operation of a facility. Platforms do not always have mooring monitoring installed, or if they do, statistics show that the system has failed shortly after installation and all the benefits of monitoring the health of the mooring are lost. With an average mooring failure projected at 8.8 years for an FPSO in the North Sea and the consequential damage this could have on the riser, indicative costs resulting in the remediation activities required for a single mooring line alone have been estimated at £2 million.[1]

After an extensive history in providing monitoring solutions for mooring line integrity, BMT has developed innovative data analytics services that utilise field data from a range of sensors. These services provide reliable and robust solutions for monitoring the integrity of a mooring system.

The Position Response Learning System **(PRLS)** has been developed for a platform that has, at minimum, a position and a motion monitoring package. By adding further sensors to acquire environmental data, the robustness and accuracy of the PRLS results are greatly enhanced.

In addition, if a platform already has a mooring tension monitoring system, the redundancy of the mooring system integrity can be improved through an enhanced service; the Tension Response Learning System **(TRLS).**

For both systems, data are treated with deep machine learning algorithms to form a platform specific, global motion response pattern. When the real-time response pattern deviates from the intact integrity pattern, the system will notify the operator about specific anomalies, providing an early warning of possible integrity issues with the mooring lines.

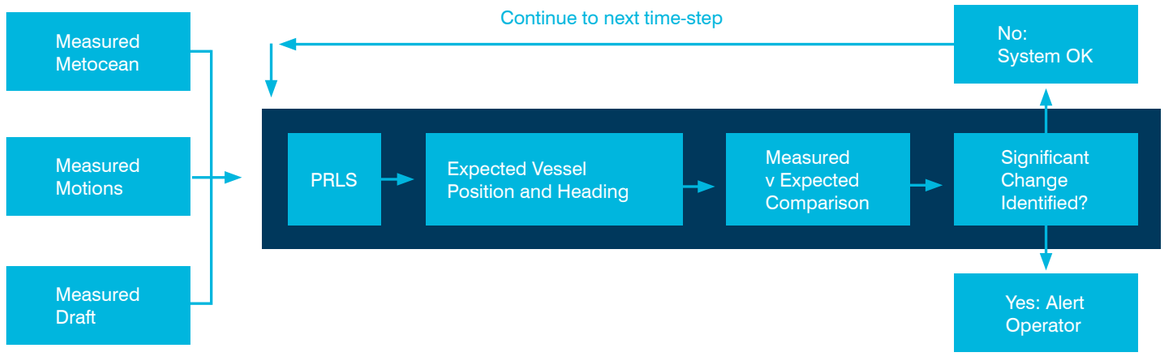
Robustness and reliability have been the key focus of this development to reduce the risk of false alarms and to supplement the scenario of a sensor failure in a conventional mooring monitoring system. This analytical approach also enables a solution for mooring integrity to be applied to vessels already in the field, avoiding the costly installation of sensors and reducing the maintenance requirements over time.

Given the commercial and safety risk associated with a mooring failure, incorporating contingency in any monitoring system through a data analysis approach is a cost effective approach for offshore facility management.

"Numerical simulations are performed for a variety of platform types and environmental conditions under different broken line scenarios.

The accuracy of detecting an alarm to identify which mooring line has failed is in general, greater than 98%."

[1]JIP FPS mooring integrity research report prepared by Noble Denton Europe Ltd for the Health & Safety Executive (2006)



Inputs required for PRLS and schematic of iterative learning process to identify a change in vessel behaviour and send an alarm to the operator.

THE AERODYNAMICS OF MODERN FLOATING OFFSHORE STRUCTURES

The wind loading acting on the topsides of floating offshore structures plays an important role during installation and operational conditions. Complexities in operations, typically ranging from landing helicopters on floating structures to side-by-side offloading of LNG, can in fact result in multiple bodies in close proximity giving rise to significant risks associated with planning and offshore operations. In regions affected by tropical extreme wind events (e.g. hurricanes and typhoons) wind loading also represents a highly influential factor in design.

Despite its importance in design, there is surprisingly little established guidance on the determination of wind loads to be used during the early stages of the design process.

Typically, during the early design stages, designers would rely on semi-empirical methods (e.g. the building block approach), often calibrated against wind tunnel results previously obtained for similar structures. While these approaches can, in principle, lead to a reasonable first estimate of the wind loads, the growing size, scale and complexities of modern offshore structures increasingly renders the use of almost any existing database of wind load coefficients less and less reliable and more prone to under-estimation.

It is within this context that in 2014 MARIN and BMT decided to initiate a JIP on 'Wind Loads': a consortium of 5 partners (which included 3 wind tunnel facilities), 12 participants from the Oil & Gas industry and a total budget in the excess of EUR 700k delivered – 3 years down the line – a very comprehensive study report on the effect of wind loads on an FPSO and a TLP from both an experimental (wind tunnel) and numerical (Computational Fluid Dynamics) perspective.

Gaining from that experience, BMT is now also involved with the SNAME OC-8, a panel of experts that is in the process of drafting a new set of guidelines on wind technologies, bringing in our integrated knowledge of wind engineering through established experimental and numerical methodologies.

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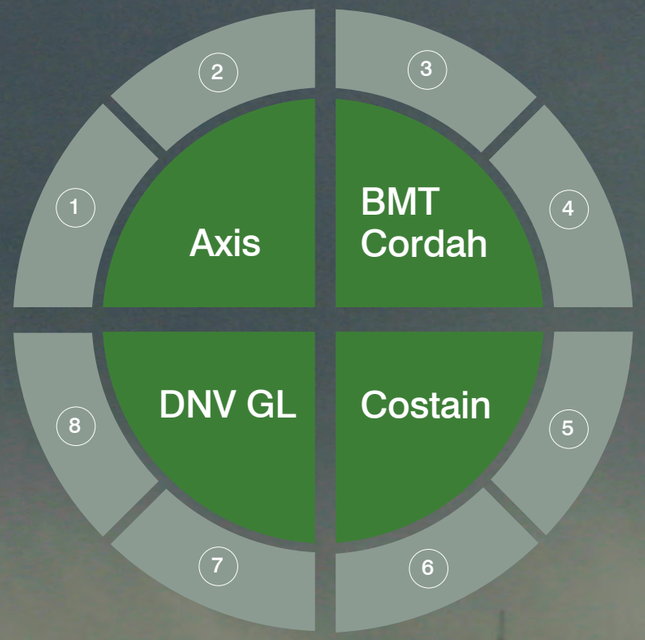
Integrated DECOM

A specialist team of companies have come together as part of their commitment to deliver an approved decommissioning programme under one collaborative offering. Integrated DECOM will offer independent front-end engineering and environmental solutions providing integrated support for oil and gas operators looking to retire redundant facilities without the burden of an in-house overhead.

With over 20 years' expertise and knowledge of successfully delivering the major UKCS decommissioning projects to date, Costain, Axis Well Technology, BMT and DNV GL have the capability and capacity to deliver the entire decommissioning work scope up to the approval of the project's decommissioning programme, from subsurface to structure, through a single point solution.

"The companies within Integrated DECOM bring complementary, critical technical skills which are required to plan and deliver compliant and cost effective decommissioning. This unique combined knowledge ensures that every solution will be considered in a comparative assessment process, delivering a lower risk and cost, decommissioning outcome for owners and stakeholders."
Frazer Mackay, Costain, Consortium Leaders

A UK FIRST FOR **DECOMMISSIONING MARKET**



Total service
Single source

A complete front-end solution for the preparation and delivery of your offshore decommissioning programme.

Axis

1: Subsurface
- COP and MER support
- Full subsurface understanding using 3D modelling

2: Wells
- Integrity status updates
- Risk reviews
- Cost estimation
- P&A programme development

BMT Cordah

3: Environmental
- EIA & Comparative Assessment
- Decommissioning Programmes
- Pre & post decom survey design
- Cuttings pile management
- Permits & consents

4: Societal
- Economic analysis
- Energy & emissions analysis
- Fisheries impact studies
- Cumulative impacts
- Risk Assessments

Costain

5: Subsea
- Flushing plan
- Pipeline Works Authorisation
- Infrastructure removal
- Legacy management

6: Facilities
- Well bay adaption
- Pipe re-routing
- Equipment isolation
- Topside modifications

DNV GL

7: Safety
- Technical safety support
- Safety case development and regulatory compliance support
- Safety studies, assessments and risk management
- Critical element management and verification
- Technology assessment and qualification

8: Marine operations & Structure
- Marine Consultancy
- Marine Safety Management
- Marine Advisory Services
- Topsides and Jacket Lift Method Studies
- Weight Verification Studies

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HABITAT MAPPING

Offshore developments often pose a risk to seabed habitats and their associated biological features. For example, dredging or dredge spoil disposal, as part of the construction of oil and gas infrastructure, may disturb or smother corals, seagrasses and macroalgae on the seabed.

Laying of pipelines or subsea cables requires trenching and may physically impact seabed habitats. Similarly, retirement or decommissioning of offshore facilities may require the use of jack-up rigs, which impact the seabed, to remove facilities.

Furthermore, sensitive habitats usually need to be avoided under government approvals. Therefore, an understanding of the seabed habitats enables proponents to avoid certain areas, manage or mitigate risks and achieve environmental approvals.

BMT regularly conducts habitat mapping on behalf of its energy clients using a range of datasets and advanced remote sensing methods tailored to the clients' needs. For example, BMT recently conducted a deep water survey in 850m of water to assess potentially sensitive habitats, prior to drilling, for an oil and gas development. Sidescan sonar and multibeam echo sounder data were used to map seabed features and understand sediment types.

An ROV with high definition video cameras was then used to collect footage along transect lines of over 20km of the seabed. Standardised survey protocols developed by BMT were used to ensure high quality footage and positioning accuracy of the ROV. Our in-house experts analysed the footage using purpose built software to identify seabed biota and substrates.

BMT has also delivered habitat mapping services to energy clients for decommissioning of offshore facilities and construction of gas processing facilities (page 12). We employ experienced remote sensing analysts to interpret and integrate imagery with spatial data, biophysical models and field measurements.

By drawing on marine science, engineering and statistical expertise and by maintaining awareness of emerging remote sensing techniques, BMT provides innovative yet commercially focused remote sensing and habitat mapping solutions. BMT can provide expert marine remote sensing advice and manage projects from commissioning imagery capture through to data analysis, mapping and reporting.

"Habitat mapping is used to reduce risks to the marine environment from proposed developments. It provides important information about the type and extent of seabed biological assemblages (plants and animals) and to identify receptors that may be sensitive to impacts."

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BMT EXPANDS
SIMULATION CAPABILITIES

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KEY RISKS MITIGATED BY SIMULATION:

- Unanticipated low return on investment / project failure due to overestimating operability by not considering complex sea-states;
- Unsafe arrivals and departures due to effect of cross-seas on arriving or departing carriers/ tankers;
- Grounding of floating equipment with consequences for high value equipment and of blocking a seaway

KEY DESIGN AND OPERATION CONSIDERATIONS

- Independently controlled tugs;
- 6 Degrees of freedom;
- Weathervaning systems;
- Ship to ship transfer;
- Wind, wave and current shielding;
- Global metocean data;
- CFD;
- FPSO's FLNG's and FSRU's

A SIGNIFICANT TRACK RECORD

- Atlantis
- Thunderhorse
- Olympus
- Jack St Malo
- Big Foot
- Appomattox
- Numerous small barge tows

The REMBRANDT simulator has made BMT a world leader in simulating high value, safety-critical tow-outs, receiving positive feedback from our clients. Recently, BMT has extended the simulation capability with more life-like visuals and the capability to represent motions and interactions between vessels in six degrees of freedom. This puts us in a leading position for feasibility, operability, design and training.

Downtime assessment is crucial for economic and technical feasibility, ensuring that any operational and commercial risk is comprehensively assessed and mitigated. BMT use simulation to hindcast the periods when carriers cannot arrive or leave because the wind wave and current conditions would make it unsafe. BMT's vessel simulation studies can also show when the export carrier, once arrived, can remain moored and when transfer operations are possible. For example, for an LNG carrier next to a floating LNG facility, the loading arm excursions and the loads in the mooring system are simulated. Both the subsea mooring system and the mooring system between the two ships are then included in the simulation to assess the feasibility of the operation.

BMT simulation services are complemented by comprehensive metocean data and, for less conventionally shaped floating platforms, a full set of methods to establish the hydrodynamics at the heart of the models. This includes use of the ANSYS AQWA package and CFD methods. This means that for floaters not covered by BMT's extensive database of ship manoeuvring, analysts can use numerical models to generate the hydrodynamic coefficients for floaters such as TLP's or cylindrical FPSO's.

BMT have proprietary global databases of wind, waves and currents, including fully 2D wave spectra. This enables complex sea states e.g. with two swells coming from different directions to be accurately represented.

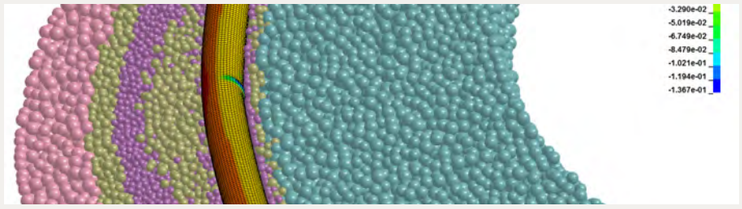
GEOTECHNICAL HAZARD ASSESSMENT FOR PIPELINES

BMT developed, validated and applied detailed 3D Pipe-soil interaction models using discrete element method (DEM) and Smooth Particle Hydrodynamic (SPH) tools to assess the impact of geotechnical hazards for onshore and offshore pipeline integrity. The long linear nature of pipelines increases the risk of interaction with a range of geotechnical hazards including active slope ground movement, ice scour, fault movement and subsidence.

The BMT DEM and SPH tools, validated against full-scale laboratory tests and comparison to pipeline system behavior, has demonstrated the ability to predict pipeline to axial and flexural loading, as well as, the onset of pipeline wrinkling or buckling.

This novel analysis tool has been developed with support from pipeline operators, the Pipeline Research Council International (PRCI) and the US Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) to support strain based design and integrity assessment of pipeline systems.

The results of geotechnical site observations and in-line pipeline inspection at the Enbridge Deadhorse Creek identified the need to understand and remediate this geotechnical hazard.



The pipeline strain accumulation was simulated to understand the integrity threat and a remedial action plan was developed. The BMT DEM and SPH tool was used to develop a strain relief program and support slope stabilization actions.

The loading and support provided by the surrounding soil considered in this large displacement geotechnical hazard could not be treated adequately using traditional soil spring models, whereas the DEM and SPH model was capable of simulating the process as demonstrated by the agreement of the model with pipeline strain gauge data collected during the strain relief program.

The DEM and SPH pipe-soil interaction modelling for geotechnical hazard strain-based pipeline integrity management and design has been demonstrated. BMT is applying this 3D modeling technique to develop engineering tools lessening the requirement for numerical simulation and describing the sensitivity of pipeline displacements and strains to the demands of geotechnical hazards.

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TRANSPORTATION STUDIES

BMT has undertaken a series of marine transportation studies.

With extensive experience of working in the Caspian region, BMT are using their local knowledge to support the transportation of numerous steel modules for offshore field development in Kazakhstan. The modules will be shipped on barges by circuitous routes including trans-ocean passages and transits through the Russian Inland Waterways System. Studies have been undertaken to assess operational and extreme sea conditions for the transportation planning and sea fastening design, and also the range of temperature and humidity conditions to which the modules will be exposed.

A comprehensive metocean study was also conducted to support the planning of the transit of Golar's first floating liquefied natural gas (FLNG) facility, Hilli, from south east Asia to its destination field, offshore Cameroon. The study included the assessment of available operational windows and expected waiting times for transit of very exposed legs of the ocean passage, together with the identification of suitable safe havens for sheltering from adverse weather.

There are various risks associated with ocean transportation of a major facility such as an FLNG vessel. Firstly, there is always the possibility of a significant storm occurring during the transit. In part, such risk can be mitigated by assessing the likelihood of storm occurrence and planning the transit during the most favourable season.

Additionally, there should be a strong passage plan in place, including detailed identification of possible ports of refuge and characterisation of available emergency anchoring or berthing facilities. A second risk relates to the actual fatigue loading imposed on the facility during transit.

The in-transit load case represents an important component of the overall assessment of the in-service fatigue life of the facility. If particularly adverse sea states are encountered during transit, this could potentially reduce the in-service lifespan of the facility, with major associated economic impact. This risk is also mitigated by detailed transit planning and careful passage execution. Other risks include health and safety aspects of transit in adverse sea states, and also financial risks from the transit taking an excessive time due to poor planning.

"BMT are using their local knowledge to support the transportation of numerous steel modules for offshore field development in Kazakhstan."

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BMT UNDERTAKES INDEPENDENT **VERIFICATION**, **OPTIMISATION** AND **REVIEW** OF WAVE AND TIDAL ENERGY DEVICES

Wave energy is generated by converting the energy of ocean waves (swells) into other forms such as electricity. Currently there are numerous technologies being developed and trialled.

Tidal energy is generated from tidal movements. Tides contain both potential energy, related to the vertical fluctuations in sea level, and kinetic energy, related to the horizontal motion of the water.

Consequently electricity can be produced through technologies using energy from the rise and fall of the tides or energy from tidal currents.

BMT has extensive engineering design experience with both Wave and Tidal Energy Devices in Australia and Internationally. Our experience includes:

- Engineering Technical Review (Mechanical, Structural, Foundations, Electrical) and Levelised Cost of Energy (LCOE) Review at various stages of all major wave energy device developments in Australia over the past 6 years on behalf of the Australian Renewable Energy Agency (ARENA)
- Advanced Analysis including Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) for a tidal current energy device
- Technical oversight of the mechanical and structural design for a wave energy device
- Test and Measurement services to trouble-shoot renewable energy projects
- Technical support with regard to tidal current turbine performance and design calculations
- Development of wave energy device performance software
- Project Risk Assessment Review at the concept stage of a wave energy device

For instance, BMT has undertaken Advanced Analysis Engineering for a tidal current device. This included CFD and FEA modelling to determine the stresses on the machine structure resulting from the applied loads due to power generation and the tidal current flows.

As a result of the initial FEA analysis BMT were able to highlight several areas of high risk, and over a series of iterations the design was optimised to meet the client's performance requirements.

Bombora Wave Power-m Wave™ Device

Image reproduced with permission

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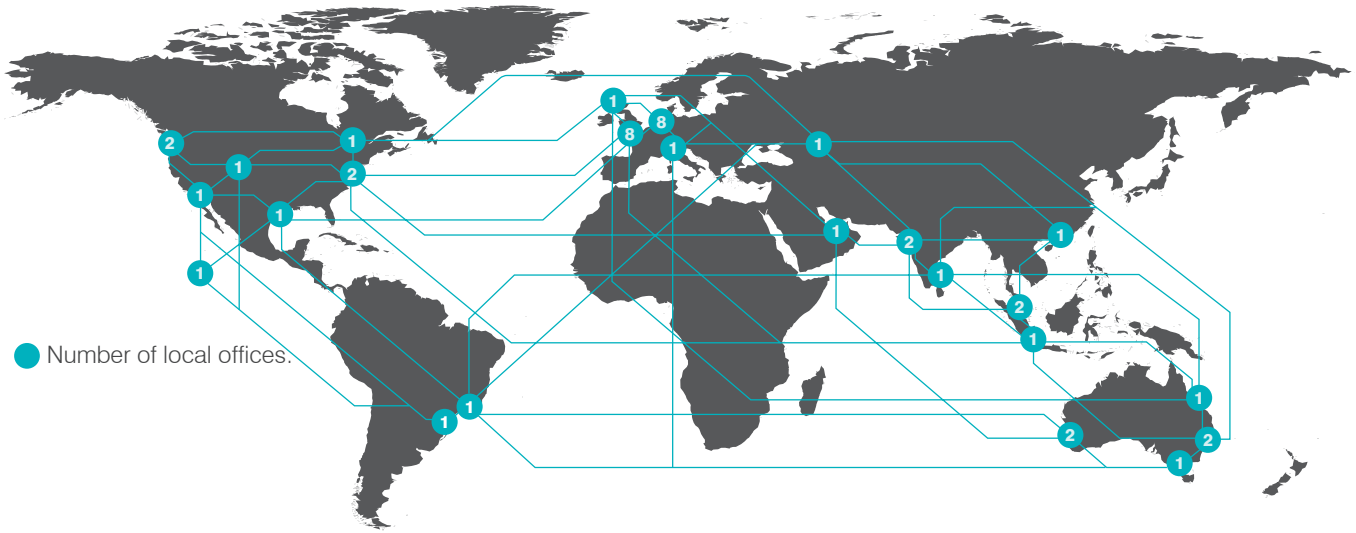
Carnegie Clean Energy – CETO6 Array (Image reproduced with permission)

BMT applies engineering, science and technology to help customers design, manage, maintain and improve their assets.

Founded on a century's heritage in the marine environment, BMT is an independent organisation held in trust for its employees.



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