Irvine Engineering

Capability Statement

“Floating Production Design Engineering Consultants”

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1.0 INTRODUCTION

Irvine Engineering was established in 1994 and is primarily a specialist consultancy company heavily involved in engineering and construction projects world-wide where it’s technology knowledge base has grown and helped develop key technical edge solutions for small and large companies within the oil and gas engineering, construction and installation global communities. What has differentiated us over the years is our ability to assist and deliver successful projects for a broad spectrum of industry Clients. One of our major strengths is the ability to easily interact within client offices and teams and quickly establish a positive presence adding value and our wealth of experience at the planning stage and thereafter to help ensure successful projects. Our services are offered from small consultancy work through to managing studies, FEED and detailed engineering covering Subsea, Platforms and Floating Production Facilities.

Irvine Engineering Provides the Following Services:

- Specialist Production and Recovery Knowledge including tank cleaning
- Study Planning and Expediting / Reporting Findings - Presentations
- Project Generation and Momentum Strategies
- Project Planning / Estimating Covering Commercial and Technical
- Project Financial Controls Including Financial Modeling
- Project Management
- Project Executions
- Quality Systems Expertise
- Marketing and Proposals

Work Expertise Areas:

- Studies Covering Downhole to Surface Production Facilities
- Fixed Platform Expertise
- Floating Production Systems Development
- Floatouts
- Vessel Inspections
- Floating Storage
- FPSO Conversions
- New Build FPSO’s
- Mooring System Designs
- Risers Systems Knowledge
- Extended Well Tests (EWT)
- Early Production Systems (EPS)
- Fixed and Floating Production Facilities Engineering
- Gas to Liquids Expertise Including LNG and PLM
- Storage Tank Cleaning with Oil from Sludge >90% Recovery
2.0 WORK EXAMPLES

Irvine Engineering recognise that for a company to distinguish itself and to be a highly successful player in the oil and gas market it needs to be at the forefront of technology where we can add value to not just today’s recovery solutions but also to new recovery concepts for tomorrow. Our track record speaks for itself and below is a typical example of on-going and recent work:

- Micro LNG for West Patricia Development Murphy Sarawak Oil Co., Ltd (detailed below)
- Micro LNG processing plant to release Stranded Gas for SPC
- FPSO Conversion for the Maari Development, OMV (New Zealand) Ltd
- Storage tank chemical cleaning with >90% oil recovery from the sludge, at three Petronas facilities, Malaysia

Example Project Description:

**Micro LNG for West Patricia Development Murphy Sarawak Oil Co., Ltd**

This is a clear work example of how Irvine Engineering can add value supplying new recovery concepts covering upstream and downstream including end users (the general public);

Irvine Engineering is assisting Murphy Sarawak Oil Co. Ltd, in the development of a pilot Gas to Liquids (GTL) project to liquefy West Patricia’s associated gases into Pure Liquefied Methane (PLM). Murphy already have a gas recovery plan implemented for recovering >250 MMscf/d together with a transportation pipeline infrastructure. Murphy’s problem is for the many gas pockets (sands) that have high CO₂ and N₂ levels and are not suitable for economic recovery or within convenient locations. Irvine Engineering presented Murphy with a solution that fits in with the current Malaysian legislation for gas usage such as LNG which is not only growing in the Far East but also globally. PLM is a close GTL to LNG but is aimed primarily as a fuel additive to diesel engines where ~80% PLM is injected at the manifold with ~20% diesel. Benefits of this includes greatly reduced fuel bill for the end user together with substantially reduced carbon and other harmful particle emissions etc. This may also be perceived as a way to extend diesel usage well into the future and if it’s emissions are greener then diesel combined with PLM will become a more acceptable fuel for the environment.

**PLM Process Description**

When natural gas is cooled down to a temperature where it becomes a liquid it is normally referred to as LNG. PLM is a version of LNG. At ambient pressure the temperature is approximately −161°C (−258°F). PLM is primarily methane with low concentrations of other hydrocarbon and non-hydrocarbon components. The following Process Flow Diagram displays how the gas is treated and converted to Pure Liquefied Methane.
**PLM Process Flow Diagram**

**Benefits:**
- Revenue route for gas disposal
- Supports current Malaysian gas legislation
- Greatly reduces or eliminates gas flaring to conserve the environment
- Greatly reduces end user diesel emissions
- Future potential to develop stranded Gas Fields (defined concept)

**Options for the Pilot Plant:**
Two flexible and re-locatable recovery options are under evaluation at this time:

**a) PLM process on a Re-locatable Spread Moored Production Barge:**

The 4.5 MMscf/d PLM Pilot Plant may be located offshore on a dumb simplified production barge (no internal storage). The plant will have a normal design gas feed (flare) capacity of 4.50 MMscf/d and total liquefied gas capacity of 4.02 MMscf/d. The basis of the Pilot Plant will be a single cycle turbo-expander refrigeration process, using self-boil-off gas as refrigerant. All of the process equipment will be skid/module mounted. Storage will be via transferable cryogenic conventional LNG containers transferred by the barge crane to a supply vessel. An alternative option also under evaluation is a new patented cryogenic transfer hose this can allow the use of a conventional LNG carrier for PLM off-take. In both PLM transfer scenarios PLM would be brought to a LNG receiving facility for an already established distribution system to end user outlets.
**PLM Production Barge Operational Sketch with LNG Carrier Off-take**

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<tr>
<td>Operating draught</td>
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</table>

*Barge Principal Particulars*

**PLM/LNG Container Shuttle Displayed at Jetty Terminal/Storage Depot**
Irvine Engineering conducted a detailed barge analysis and moorings report to support this concept based on an existing sourced candidate barge where the barge with modifications mostly to the hull was found to be within the PLM process motions acceptable limits even within a 10 year storm condition. The reason why a barge has been evaluated and is now the preferred solution is because on earlier study work all feasible production platforms were evaluated for their suitability covering practicality for Mini LNG production, installation, operations, flexibility, abandonment and overall project economics, the barge option together with a suitable barge being available made the barge the best option. As already mentioned the barge has no need for internal storage which also simplifies the design and any conversion work.

The concept consists of a spread-moored barge, located in close proximity of 40m to an existing fixed jacket platform at a water depth of 35 metres. The barge does not weathervane and is permanently spread-moored on location by conventional passive chain lines. The barge is moored with its bow facing the direction of true north. The proposed barge is a Mini LNG barge (PLM production).
Below is the planned field layout that has been optimised to fit into and best serve the existing production facilities on West Patricia.

![Optimised Field Layout Arrangement]

**b) PLM Process Mounted on a Re-locatable Platform (i.e. SERF/Jack-up)**

Another solution evaluated was for a 4.5 MMscf/d PLM Pilot Plant to be located offshore on a Self Elevating Re-locatable Facility (SERF), bridge linked to the West Patricia Platform A. The plant will have a normal design gas feed (flare) capacity of 4.50 MMscf/d and total liquefied gas capacity of 4.02 MMscf/d. The basis of the Pilot Plant will be a single cycle turbo-expander refrigeration process, using self-boil-off gas as refrigerant. All of the process equipment will be skid/module mounted.

![PLM on SERF Platform with Shuttle/Container Off-take]
This option has similar installation and re-locatable advantages to the barge design option, however, the cost of the SERF and the required modifications adapting it to PLM production does not allow the concept to compete at a practical and economic level to the barge concept displayed above. The only main advantage the SERF had over the Barge concept is that the PLM process system does not need to be designed for motions and accelerations that the barge would impose although the barge motions report we conducted proved this not to be such a large issue.

Project Status:
Currently Murphy need to stop flaring on their SK Gas field developments including West Patricia, PLM production will assist with complying to the Petronas directive and at the same time assist with offsetting OPEX by generating additional reservoir revenues. PLM has never been processed offshore but the systems are proven onshore and Irvine Engineering has made studies to confidently verify the process will work on a floating facility. It is anticipated that the floating production concept will soon be adopted by Murphy.

Work Spin-off Example - Micro LNG Processing Plant to Release Stranded Gas for SPC
The PLM conceptual design has created a great deal of interest and Irvine Engineering has been approached by companies looking for a way to utilise their associated gas into a saleable commodity. One such example is Keppel Marine and Offshore and SPC. These companies quickly need a similar Micro LNG (PLM) plant for stranded gas on an SPC field development. The bottom line to this is that Singapore will be provided with a consistent mini LNG source for small industries and NGV/CNG vehicles.

Maari Development for OMV (New Zealand) Ltd
The Maari Field is situated in the Tasman Sea offshore the west coast of Taranaki, New Zealand in licence PEP-38413 in 101m water. Maari is 80 km from the coast and 36 km from the Maui B platform and FPSO “Whakaaaropai” to the north. The Manaia reservoir is approximately 9 km south of the Maari reservoirs. The licence is held by OMV New Zealand (69%), Todd Petroleum Mining Company Ltd (16%), Delta Oilfield Taranaki Pty Ltd (5%) and Horizon Oil NL (10%). OMV New Zealand Ltd is the designated Operator.

Maari Field Location
The scope of works and services extends to and includes provision of a vessel for conversion to the FPSO and all work associated thereof. Supply of all equipment (other than OMV supplied equipment), fabricate, modify, repair, manufacture, build, construct, test, deliver, transport, install, commission, set to work, operate, maintain, provide all support services for operations.

Maari Field FPSO “Raroa”

This project is now in the construction phase and run though to 2008. Irvine Engineering is working in an alliance with Global Process Systems Pte Ltd for repair, conversion of the tanker, fabrication and installation of the process facilities. The contract value will be approximately $USD 65 million.

Break down of companies awarded the work:
• The tanker conversion Jurong Shipyard, Shipyard Road. Contract valve is S$ 25 million
• Gas Compressors –GPS Pte Ltd at contract value of S$ 10 million
• Process Equipment –GPS Pte Ltd at contract value of S$ 19.5 million

Mutineer/Exeter Development for Santos Ltd
The Mutineer and Exeter fields are located offshore NW Australia in permit area WA-191-P(1) in water depths between 145-161m. The development is for an FPSO equipped with a disconnectable turret mooring (DTM) system, and subsea completions. Two production centres at Mutineer and Exeter will be tied back via a system of flowlines, well service lines, control / power umbilicals.

The fields contain light crude oil (43o API) with a low gas-oil ratio. The flowing wellhead design temperature is expected to be 110°C. The absence of any significant gas for re-injection and the envisaged decline in reservoir pressures requires the development strategy to employ both down-hole electrical submersible pumps (ESP’s) and mudline booster pumps.

Break down of companies awarded the work:
• The tanker conversion Jurong Shipyard, Shipyard Road. Contract valve is S$ 25 million
• Subsea Trees – ABB Vetco Gray Pte Ltd at contract value of S$ 6 million
• Gas Compressors – Gas Services International Pte Ltd at contract value of S$ 5 million
• Process Equipment – Dyna Mac Pte Ltd at contract value of S$ 7.5 million
Marine Installation - Halliburton Far East Engineering Pte Ltd at contract value of S$10 million

**Mutineer/Exeter Development FPSO**

**Agip Australia - Woollybutt FPSO Project**
The Woollybutt project would not have been triggered if not for Irvine Engineering's expertise in the development of small marginal oil and gas reservoirs. The Woollybutt Field is located off the North West coast of Australia, approximately 80 km north of the town of Onslow in the Carnarvon Basin. The field lies on the continental shelf in approximately 100m of water. Based at that time on the results of the appraisal program, Woollybutt recoverable reserves are estimated to be approximately 20 million barrels of oil and the field is currently anticipated to be in production for approximately three years. The Woollybutt development will be designed for two subsea wells connected to a floating production system. The oil production from the Woollybutt wells will be up to 40,000 BOPD.

The Floating Production Storage and Offloading facility is a converted existing tanker ("M/T Four Lakes") which will have process equipment installed on the deck.

**Break down of companies awarded the work:**
- The tanker conversion “M/T Four Lakes” to FPSO “Four Vanguard” Keppel Shipyard Benoi Road. Contract value is 20 m S$.
- Subsea Trees – ABB Vetco Gray Pte Ltd at contract value of 6 m S$
- Gas Compressors – Gas Services International Pte Ltd at contract value of 7 m S$
- Process and mooring equipment – Dyna Mac Pte Ltd at contract value of 3.5 m S$
- Marine Installation - Halliburton Far Engineering Pte Ltd at contract value of 5 m S$
Shell Philippines Exploration B.V. - Malampaya Project
The Malampaya Field is located in license block SC 38 of the South China Sea in approximately 850 m water depth, situated 75km North West of El Nido in Palawan Island, some 400km South West of Manila. The partners in the field are Texaco, PNOC and Shell Philippines Exploration BV (SPEX). SPEX are the operator.

- Integ Deck – Sembawang Marine Engineering Pte Ltd at contract value of 200 m S$
- Marine Installation - Halliburton Far East Engineering Pte Ltd at cont val of S$ 10 m
- Subsea System – Cameron Pte Ltd at contract value of S$ 20 m

Shell Malampaya Floatover Operation
**Petronas Carigali - Ruby Field**

The Ruby Princess FPSO is operating in the Petronas Carigali Ruby Field located in Blocks 01 & 02 offshore Vietnam, approximately 155 km northeast of Vung Tau. The FPSO Ruby Princess is a converted tanker (formerly the Knock Davie) of 140,000 dwt, processing approximately 30,000 bopd from a Wellhead platform (WHP). The well fluids are transferred from the WHP to the FPSO via a 10” subsea flowline, 1.3 km long. The well fluids are processed through a single, three phase separation train. The crude oil is then exported via offtake tanker (once per month) and the gas is flared. The FPSO started the oil production in 1998.

![The Ruby Princess FPSO](image)

**Petronas Miri, Melaka and Terengganu TCOT, Malaysia – Tank Cleaning**

Irvine Engineering are working closely with Vision Petroleum Malaysia whom has successfully introduced their unique sludge cleaning chemical at three different Petronas tank sites where it out performed company expectations. Since these initial pilot projects the chemical has undergone further refinement resulting in an improved version which Irvine Engineering are assisting Vision Petroleum with bringing the tank cleaning service to a global market.

![Petronas Terengganu - TCOT](image)
Main particulars are:

- Low temperature, nano chemistry hydrocarbon recovery agent.
- Surfactant based sand control chemical.
- Low temperature, nano chemistry heavy oil viscosity modifier.
- Low dosage nano chemistry core demulsifier.
- Nano chemistry sand oil surfactant.
- Universal parafinic pour point depressant.
- Rapid oil-water separation (10-20 minutes);
- Separated water has 10.6 -12.4 ppm oil content, which is within operational limit of 30 ppm (Petronas Standard);
- No re-emulsification even after re-agitation;
- Complete BS&W reduction at higher dosages (60 ppm);
- Tested for crude compatibility with no impact - density, metal content (100% organic), sulfur (ASTM D4294), mercury (UOP 398), salt content.
- Fluidized sludge by reducing viscosity (80-90%).
- No cooling impact - fluids mobile at 20°C.
- Works at ambient temperature - no heating required.
- No re-emulsification with clean crude (diluent) - 100% solubility in hydrocarbon solvent.
- Separated solids are water-wet.
- Surfaces are water-wet.
- No impact on Micro Carbon Residue Test (ASTM D4530) i.e. will not cause fouling on metal surfaces.

Terra Nova Ice Class FPSO

3.0 FLOATING PRODUCTION SYSTEMS EXPERTISE

Overall EPCI Support Capability

Irvine Engineering consultancy services specialise in the engineering and construction of floating production vessels with a wide range of expertise from studies, conceptual designs, front end engineering, detailed engineering to final installation.
Our floating production vessel engineering, procurement and project management offices are located in Singapore and Malaysia, with additional significant skills and resources available in other companies that we regularly have partnerships with to assist clients with more intricate problems and solution findings, as no single company can be a complete solution finder!

Irvine Engineering can assist with implementing all required project management tools and systems including Quality Systems to manage all sizes of projects including technologically complex projects. We maintain an Integrated Project Management System (IPMS) for planning and controlling the engineering, procurement, construction and installation phases of a project and integrate these into a single software solution. IPMS comprises a number of applications sharing a common database thereby ensuring consistent reporting for project management and materials management functions. These applications include:

Irvine Engineering maintain a core experienced design team and can also quickly mobilise our regularly contracted Chartered Engineers as manning levels increase within a project. Our engineers and technicians can cover over 100 disciplines and specialities. To facilitate the engineering activities, Irvine Engineering maintains a powerful and technologically advanced suite of software. This comprises both commercially available software and internally developed expert software for the analysis and optimisation of all forms of production systems.

- Cost control
- Document Management
- Materials Requirements Planning
- Procurement
- Site Control
- Construction/Installation Support

4.0 NEW TECHNOLOGY AND INNOVATION

Irvine Engineering engineers have a company culture and track record for developing innovative concepts and for tackling technologically challenging or advanced projects. An ability to develop the optimum solutions is, we believe, why customers have given us so many challenges. Irvine Engineering has successfully assisted with the execution of many projects. Reliability, support and innovative design skills can offer benefits to the Client, and this is constantly reflected in our design solutions.
Taut Moorings

Irvine Engineering understand the importance to developing new conceptual designs engineered to meet today’s economically driven solutions from benign to extreme environments from 60 metres to three thousand metre water depths.

Irvine Engineering recognises that technologically up to date developments are key factors that will enable our Clients to produce oil and gas from remote and deep water assets that may not otherwise be economically recoverable. This is why we are committed to technology and why our technical edge is passed onto our Clients, this is the driving force behind our designs and proposals.

Maintaining Schedules
Irvine Engineering has the capability to design and engineer, from concept to final commissioning and installation, floating production systems and Tension Leg Platforms optimised to maximise the field Net Present Value (NPV) for the Client. This can only be achieved by careful and logical management of project schedules and costs. This relies heavily on the process of informed decision making which can only be achieved by the use of efficient integrated project management systems and risk management systems based on logic and engineering data. In addition to the earlier described IPMS management system, Irvine Engineering operates a structured and highly effective Commercial Risk and Opportunity Management process in response to challenges posed by increased project complexity, increasingly ambitious project schedules and increased focus on bringing projects within budget estimates.

5.0 CONCEPTUAL DESIGNS
Irvine Engineering understand the importance of maintaining a research and design commitment this is why we have a design portfolio offering various standard and novel conceptual design that can be adapted to be used in many recovery scenarios. Below represents a broad sample of our design portfolio.

TLP Conceptual Design
This is a large Tension Leg Production Platform suitable as a stand-alone facility supported by an export pipeline system or a floating storage unit. It may also be utilised
as a central Hub Facility supporting a number of developments. It has a displacement of 99,800t and the supporting hull measures 103 x 103 x 70 metres. Positioning is via a taut mooring configuration with four tethers at each corner of the hull. This platform has exceptionally good motion characteristics confirmed by extensive model tests. The platform design conforms to the most stringent safety and environmental requirements specified by international regulations and standards. The hull is made up from a ring pontoon arrangement and four round columns for supporting the topsides. The design is robust and allows for easy construction. Due to it’s large topside carrying capacity, the platform is capable of supporting large process systems, all utilities systems, an accommodation block for up to 120 persons and drilling facilities. The drilling derrick is positioned over a central moonpool. Tensioned risers are received via the central moonpool. This concept allows dry trees to be used.
Push Barge Shuttle Tanker Concept
This concept is a push barge system design which has a standard tanker hull form with the addition of a modified aft end designed to receive a pusher tug. Typically two pusher tugs working with four barges will transport well fluids from either an offshore platform or an export terminal to a receiving terminal. The system offers significant CAPEX reductions and increases in operational efficiencies when compared with conventional shuttle tankers on short sea routes. The BAR-PUSHER 25 concept is currently proposed for a major crude oil shipping operation across a short sea route.

Small FPSO - 25000 m³
The vessel is a ship shaped conceptual design FPSO designed to meet the needs of small or marginal fields. Capable of handling up to 8 risers with options for station keeping by turret based moorings or dynamic positioning with Azimuth / tunnel thrusters.

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<td>EWT / EPS or Base for Well Services</td>
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Methanol & Oil Large FPSO - 65000 m³
The vessel is a ship shaped FPSO producing stabilised crude and methanol. The vessel was designed to meet the needs of moderate sized fields. Capable of handling up to 5 risers with station keeping through either dynamic positioning or turret based moorings.

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Semisubmersible Platform 100,000 te
The design is a large Semi-submersible production platform suitable as a stand-alone facility supported by an export pipeline system or a floating storage unit. It may also be utilised as a central Hub Facility supporting a number of developments.

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LNG Floating Storage Unit (LFSU)
The design is a medium sized concrete LNG storage facility with an option for production. It is spread moored via either 12 or 16 mooring lines depending on location. This design incorporates a topside design and layout unique to Irvine Engineering.

![LNG Floating Storage Unit](image)

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FSU 103,000 m³ (new build)
The vessel is a ship shaped FSU designed to meet the needs of large harsh environment deepwater fields. Station keeping through a freely weather vaning bow turret mooring system with heading control thrusters.

![FSU 103,000 m³](image)

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<td>Benign to Severe</td>
<td>Alternative Use:</td>
<td>FPSO</td>
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<tr>
<td>Length:</td>
<td>229.6 m</td>
<td>Construction:</td>
<td>Double hull steel structure</td>
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<tr>
<td>Breadth:</td>
<td>40.0 m</td>
<td>Docs. Available:</td>
<td>Conceptual Design Report, General</td>
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<tr>
<td>Depth:</td>
<td>22.0 m</td>
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<td>Arrangement Drawings, Structural</td>
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<td>Oil Storage:</td>
<td>103000 m³</td>
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<td>Arrangements, Turret Design,</td>
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<td>Analysis Report, Marine Systems</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Schematics, Technical Specification</td>
</tr>
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</table>
Multiple Field / Self Transferable FPSO

The vessel is a ship shaped FPSO designed to meet the needs of short field life's or marginal fields. Capable of handling up to 8 risers with station keeping through DP utilising Voith Schneider propellers or conventional thrusters.

Design Status: Concept  Topsides: Plug and Play (35000m3/d)
Application: Benign to Moderate  Alternative Use: EWT / EPS
Length: 130.0 m  Construction: Double hull steel structure
Breadth: 41.76 m  Docs. Available: General Arrangement Drawings, Tank
Depth: 18.0 m  Plans, Structural Arrangements,
Oil Storage: 48000 m3  Marine Systems Schematics, Outline
Technical Specification

FPSO Barge Shaped Floater 51,000 m³

The unit is a low cost benign environment FPSO designed to meet the needs of marginal to large fields. A fully completed topsides facilities can be skidded in a single piece onto the hull thus minimising hook-up and commissioning activities. The vessel has a very large topsides weight carrying capacity. Typically capable of handling up to 15 risers. A simple spread mooring system is used for station keeping.

Design Status: Concept  Topsides: Field Specific – Weight 20000 te
Application: Benign  Alternative Use: FSU
Length: 116.14 m  Construction: Double hull steel structure
Breadth: 62.0 m  Docs. Available: General Arrangement Drawings, Structural
Depth: 14.5 m  Arrangements
Storage: 51000 m3
**Model Testing**

Irvine engineering experience includes model testing support and verification work which is conducted at several global model test facilities. Floating conceptual designs are engineered utilising CAD facilities and Naval Architects together with Marine engineers where then the designs are proven via model testing where extensive tests for environmental forces can be carried out including seat states, wave periods, wave heights and green water effects etc. This vital model testing data can verify the validity of a design and offer vital design modification information.