MARINTEK do Brasil - Opening Seminar
19th April 2007, Rio de Janeiro

Advances in Design, Installation and Operation Analysis of Offshore Pipelines

Egil Giertsen, MARINTEK

Presentation Outline

- Background
  - Offshore pipeline R&D projects
  - The Ormen Lange gas field
- SIMLA development strategy
- SIMLA analysis functionality - highlights
  - Examples from the Ormen Lange project
- Use in the oil and gas industry
- Plans

PIPESTAB JIP (1983-1988)

- **Executive partners:** MARINTEK
- **Sponsors:** ExxonMobil, Statoil
- **Objectives:**
  - State of the art before PIPESTAB: *Dnv 1981 Rules for Submarine Pipeline Systems* => High concrete coating costs
- **Outcome:**
  - Reduced concrete coating thickness => Cost savings
  - Computer programs PIPE and PONDUS => CARISIMA/Beta
  - DnV RP E305

SUPERB JIP (1992-1996)

- **Executive partners:** MARINTEK, Snamprogetti and DNV
- **Sponsors:** ExxonMobil, Conoco, Statoil, EMC, HSE, Agip, Norsk Hydro, NPD, Shell
- **Objectives:**
  - Reliability based design of Submarine Pipelines
  - State of the art before SUPERB: *DnV 1981 Rules for Submarine Pipeline Systems*⇒ High steel costs
- **Outcome:**
  - Code calibration resulted in increased utilization (0.72 -> 0.80)
  - Reduced wall thickness => Cost savings
  - DnV Offshore Standard F101 (DnV 1996)

DEEPIPE JIP (1996-1999)

- **Executive partners:** MARINTEK, JP Kenny and DNV
- **Sponsors:** NFR, Conoco, Statoil, Phillips, Allseas, ETPM McDermott
- **Objectives:**
  - Qualify existing Lay vessels for Deep Water Laying allowing overbend strains up to 1%
  - DnV 1996 ⇒ Maximum strain during installation of 0.5%
- **Outcome:**
  - Increased allowable strain (0.5% -> 1.0%)
  - Possibility of using existing lay vessels also in deeper waters
  - DnV Guideline for Deep Water Pipelines

CARISIMA JIP (1999-2002)

- **Executive partners:** MARINTEK, Statoil
- **Sponsors:** Norsk Hydro, Statoil, Conoco, BP, Texaco, ExxonMobil, Agip, Petrobras, Halliburton, Technip-Coflexip
- **Objectives:**
  - Develop a pipe-soil interaction model suitable for detailed analysis of TDP effects for catenary risers
  - Verify the numerical model by 2D geotechnical small-scale tests (performed at NGI)
  - Validate the model by back-calculation of monitored in-situ full scale test data
- **Outcome:**
  - A numerical pipe-soil interaction model applicable for on-bottom pipeline stability and TDP effects for catenary risers
  - More accurate prediction of fatigue life and extreme stresses

INT-STAB JIP (2003-2006)

- **Executive partners:** DNV, MARINTEK and DHI
- **Sponsors:** Statoil, Norsk Hydro, Woodside, PRCI
- **Objectives:**
  - A Recommended Practice for On-bottom Stability Design (replacing DNV RP E305)
  - Up-to-date know-how with respect to sediment transport
  - A new PONDUS database for clay type soil
  - A completely revised version of the PIPE software for on-bottom stability analysis
- **Outcome:**
  - DNV RP F109 (currently on external hearing)
  - New PIPE version v3.02

DEEPLINE SIP (2003-2006)

- **Executive partners:** MARINTEK
- **Sponsors:** RCN, Norsk Hydro, Statoil
- **Objectives:**
  - Development of new analysis tools for offshore pipelines
- **Outcome:**
  - SIMLA – a special purpose computer tool for engineering analysis of offshore pipelines during design, installation and operation

CORROSION FATIGUE JIP (2001-2008)

- **Executive partners:** MARINTEK, SINTEF
- **Sponsors:** Petrobras, Statoil, ConocoPhillips, Total, Norsk Hydro, Acergy, Technip, NKT, Wellstream
- **Objectives:**
  - Steel armour layer of a flexible riser/umbilical subjected to fatigue loading
  - The environment in the annulus may become corrosive:
    - Sea water ingress due to damage of outer sheath
    - Diffusion of CO2 or H2S from bore
    - Diffusion of water vapour from bore
  - Fatigue design criteria for these environments are needed
- **Outcome:**
  - Provide basis for fatigue strength assessment of armour wire in annulus environments

UMBILICAL JIP (2005-2007)

- **Executive partners:** MARINTEK
- **Sponsors:** Petrobras, Norsk Hydro, BP, Shell, Nexans
- **Objectives:**
  - Development of next-generation software tools for stress and fatigue analysis of umbilicals
  - Verification and validation by full-scale testing
  - Case studies
- **Outcome:**
  - The UFLEX Program System
  - Laboratory test results
  - Case study reports

FLEXIBLE RISER DESIGN FORMAT JIP (2003-2007)

- **Executive partners:** MARINTEK
- **Sponsors:** Petrobras, Statoil, BP, Wellstream
- **Objectives:**
  - Enhanced Fatigue Design Formats for Flexible Risers
    - Establish refined statistical models of relevant parameters
    - Perform additional case studies
    - Develop simplified case-based procedure
    - Evaluation and categorization of safety factors
- **Outcome:**
  - Guideline on case specific fatigue design factors
  - Measurements and analysis results from field test data, full-scale laboratory tests and small-scale tests
  - Case study reports

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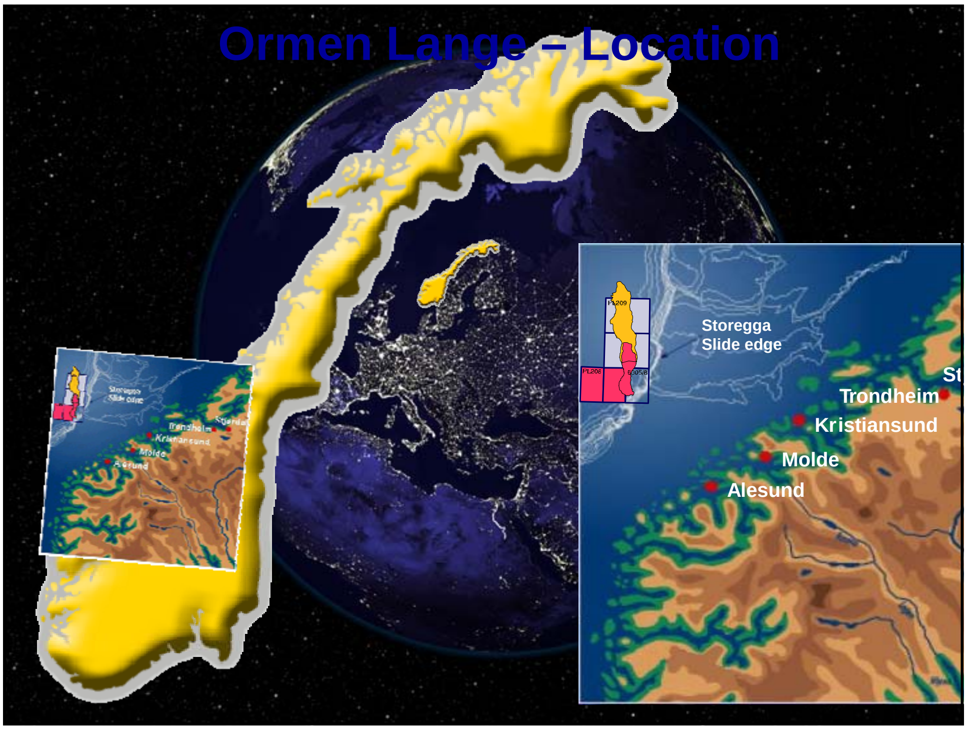
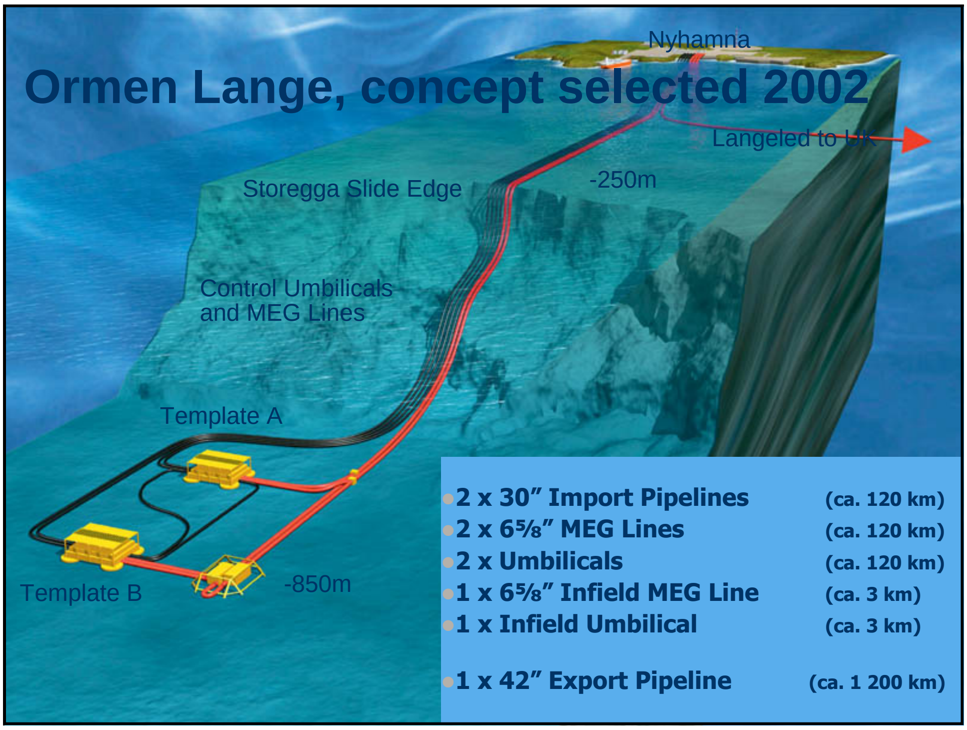


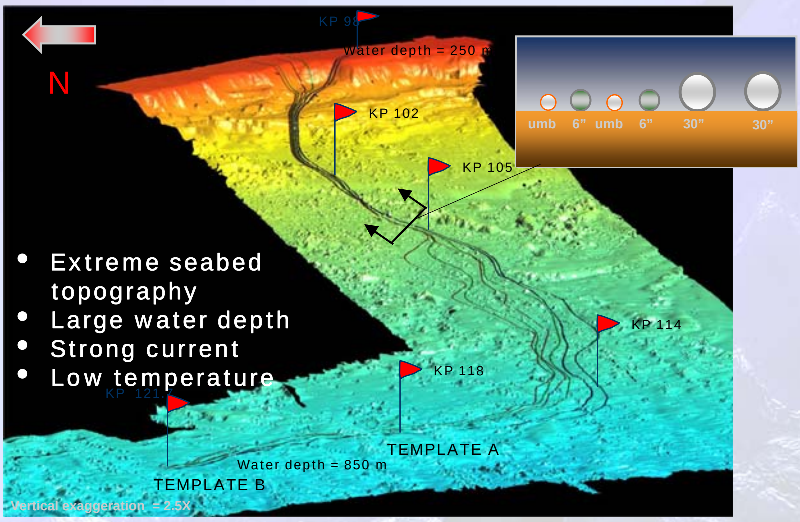
Ormen Lange, concept selected 2002



- 2 x 30” Import Pipelines (ca. 120 km)
- 2 x 6⅝” MEG Lines (ca. 120 km)
- 2 x Umbilicals (ca. 120 km)
- 1 x 6⅝” Infield MEG Line (ca. 3 km)
- 1 x Infield Umbilical (ca. 3 km)

- 1 x 42” Export Pipeline (ca. 1 200 km)

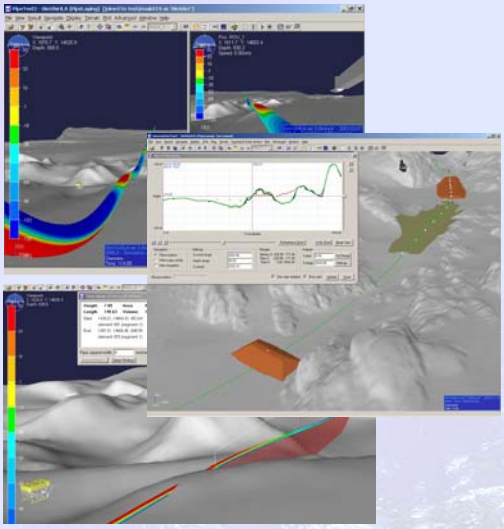
Ormen Lange … the ultimate challenge for offshore pipe laying



- Extreme seabed topography
- Large water depth
- Strong current
- Low temperature

SIMLA

a special purpose computer tool for engineering analysis of offshore pipelines during design, installation and operation

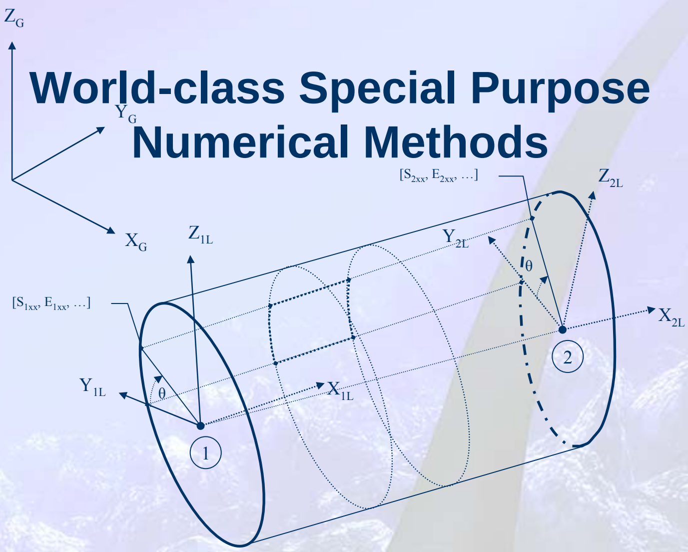


- Nonlinear 3D FEM static and dynamic analysis
- Simulation of pipe laying
- Evaluation of laying stability
- Upheaval buckling and snaking analysis
- Inspection and evaluation of free spans
- Training and familiarization
- Route planning and optimalization
- Seabed interventions
- Prediction of vessel position
- Operator guidance

Development Strategy

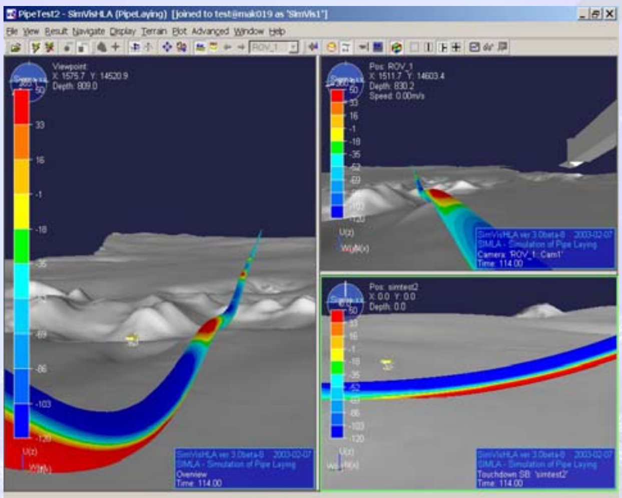
Technology Development Philosophy

World-class Special Purpose Numerical Methods



Technology Development Philosophy

World-class 3D Visualization



Lifecycle Approach

Field development	Design	Installation	Operation
• Concept development • Technology and concept evaluation • Environmental issues • Risk	• Routing/optimization • Seabed intervention	• Interventions (rock dumping, trenching, dredging) • Installation procedures • Pipe installation	• Monitoring • Remaining fatigue life • Change in seabed topography • Change in operational conditions

High Level Architecture (HLA) / Run-Time Infrastructure (RTI)

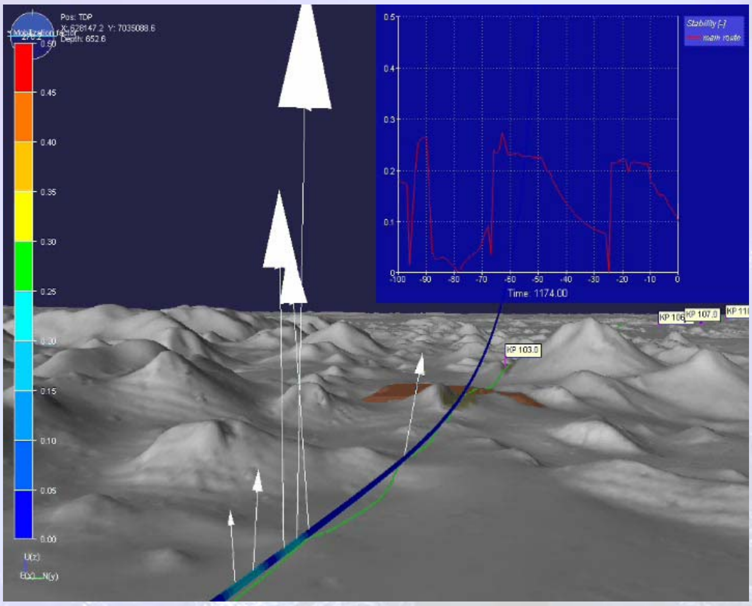
Storage and retrieval

Database

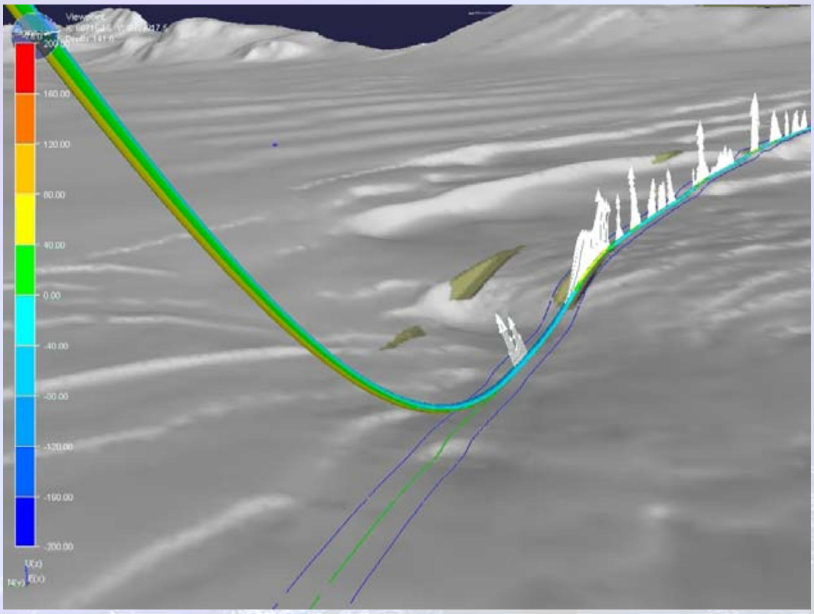
Basic Analysis Functionality

Installing a 42” Export Line (Nearshore)

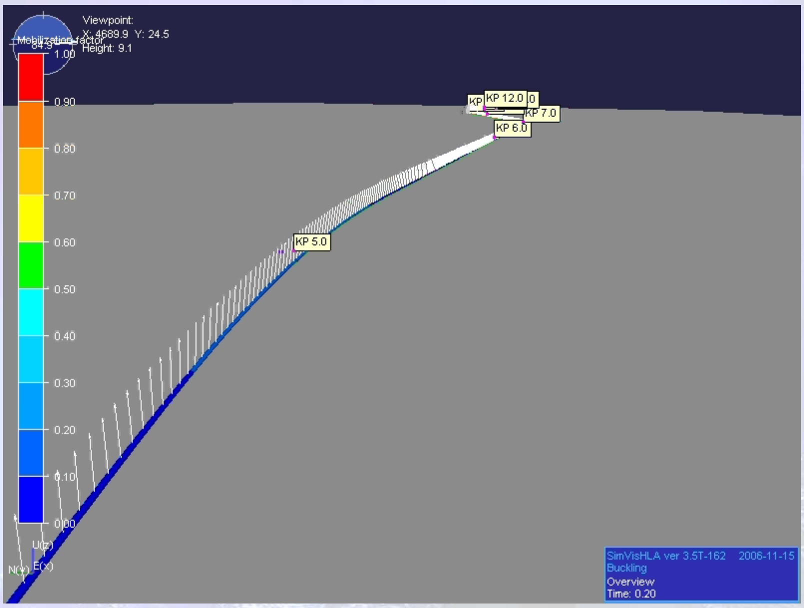
Pipe sliding in trench



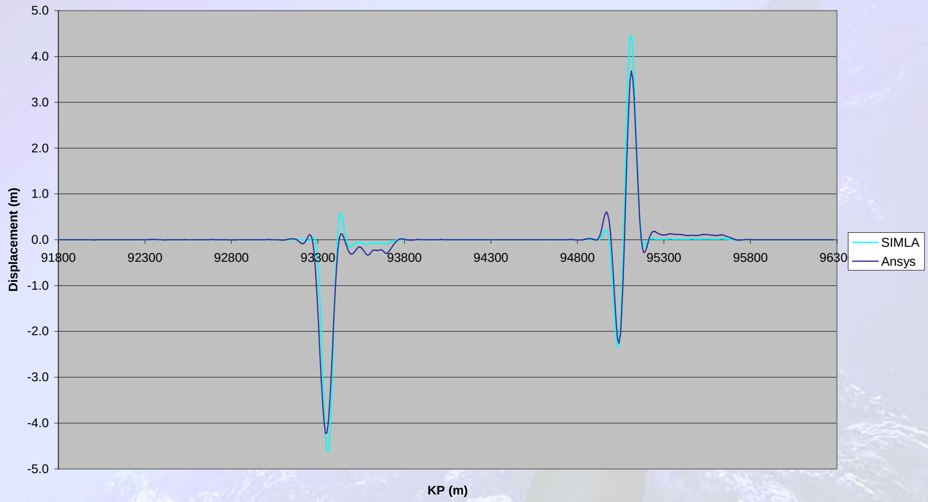
Dynamic stability



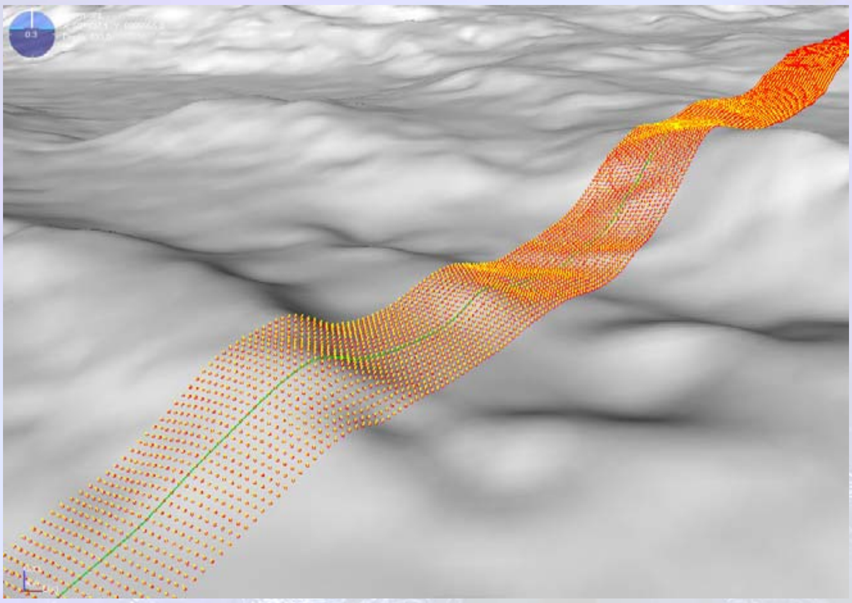
Expansion Control Analysis



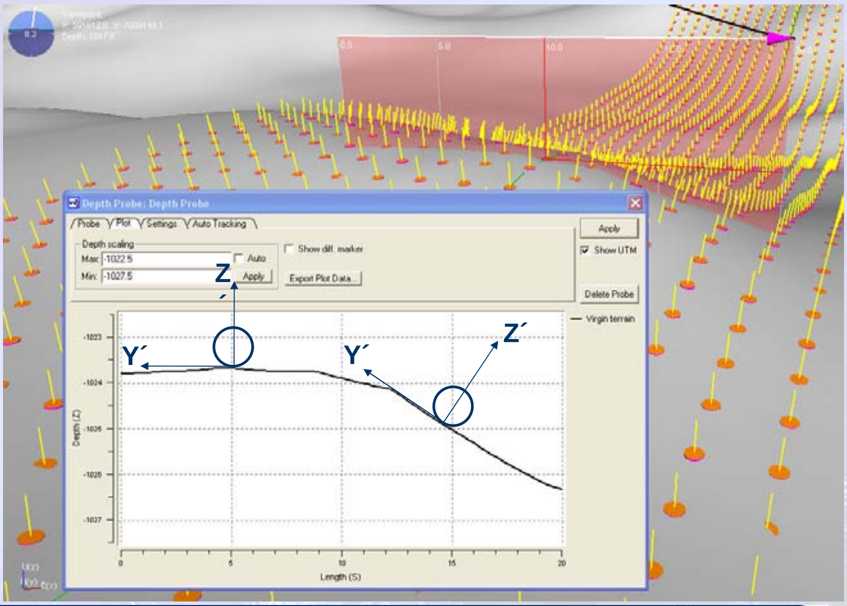
Back-calculation of snake lay design OL PL-A



Defining the 3D numerical route corridor (1)



Defining the 3D numerical route corridor (2)



Use in The Oil and Gas Industry

SIMLA in Ormen Lange

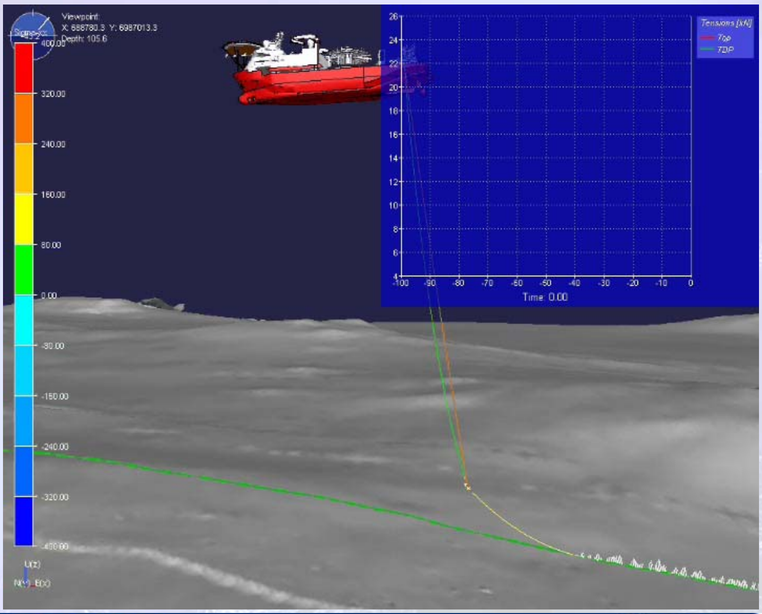
OLFP - Major Offshore Contracts

- Pipeline detail engineering
  Reinertsen
- EPC Subsea system
  FKS
- Shallow water installation
  30” & 42”
  Allseas
- Coating (weight and corrosion)
  Bredero Shaw
- Survey
  Geoconsult
- Rock installation
  Van Oord ACZ
- MEG installation
  Acergy
- Deep water installation
  30” & tie-in
  Saipem
- Umbilical production
  Nexans
- Umbilical installation
  Subsea 7
- Heavy lift
  Heerema
- Dredging
  Nexans

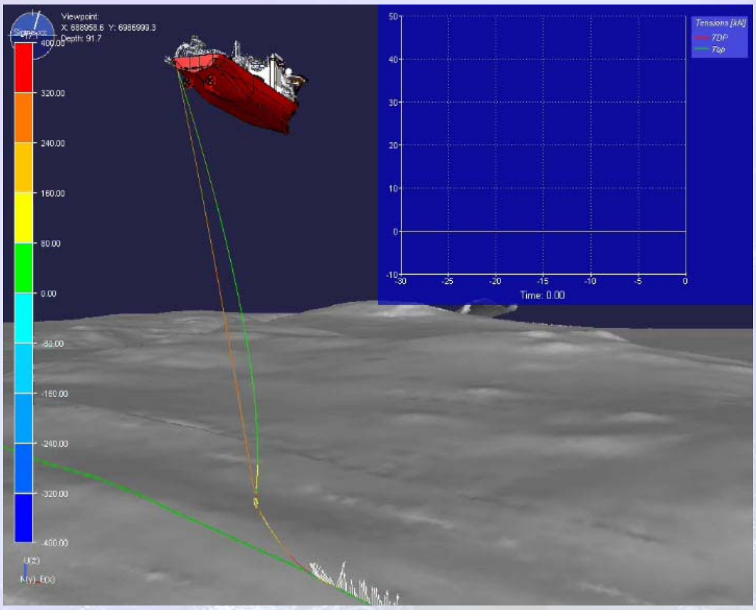
Contractors using SIMLA

Contractors with SIMLA installed

Installation Analysis of Umbilical - Static



Installation Analysis of Umbilical - Dynamic

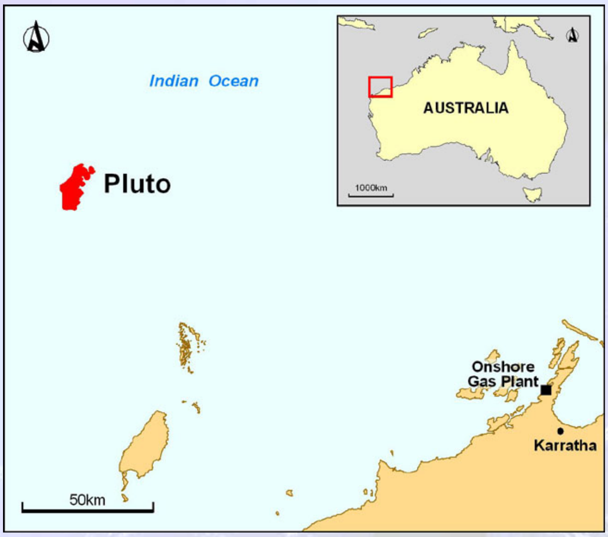


Use of the SIMLA Program System in the Ormen Lange field project has been - and is - a success

- Communication
  - Partners
  - Media
- Familarization
  - Project team
  - Contractors
- Design and construction
  - Verification and validation (specialist analysis)
  - Interface meetings with contractors
  - Company representative on board lay vessels

A 3D visual model of the complete field layout has grown as the project has moved forward, and is now believed to be used also during operation

The Pluto Field - Overview



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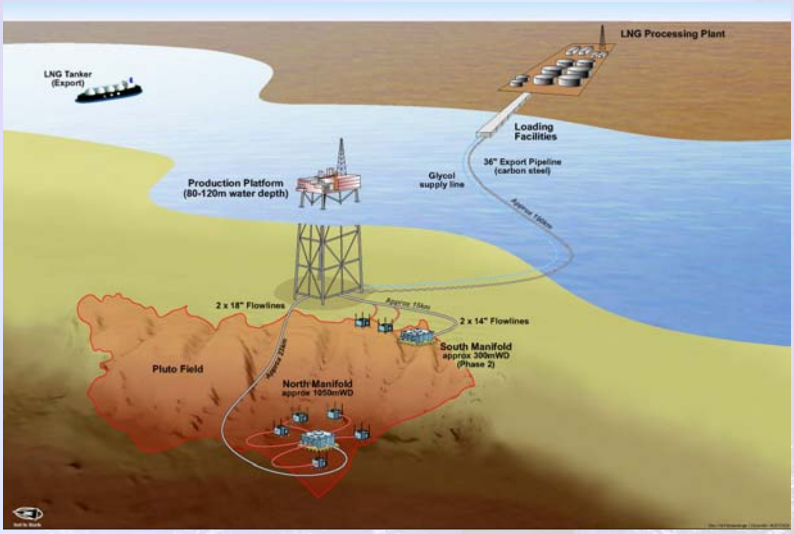
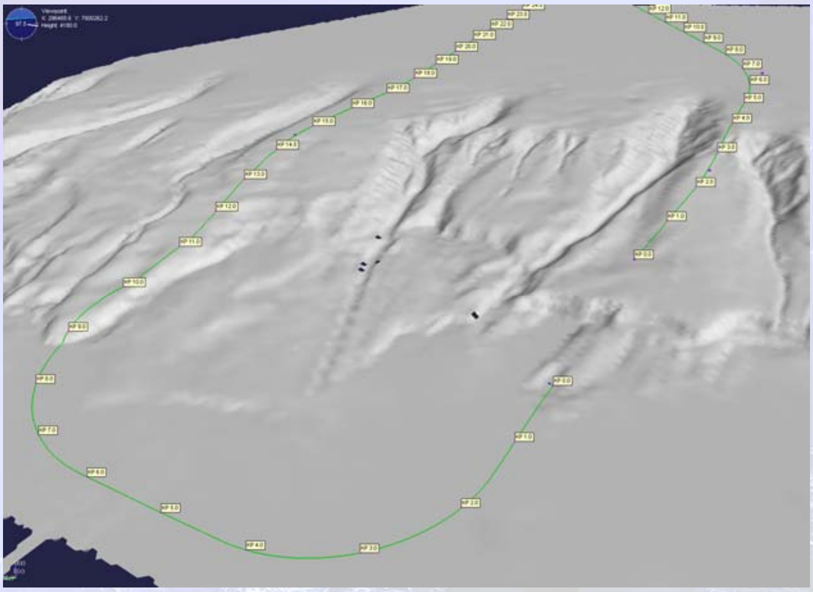
Planned Development Solution

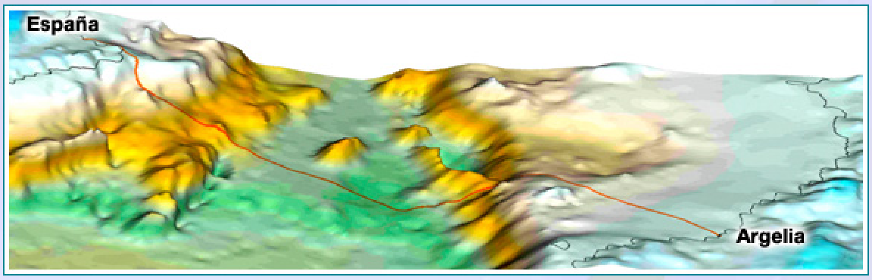


Woodside Energy Ltd

The Seabed at The Deepwater Area



The MEDGAZ Project (www.medgaz.com)



Capacity:	8 billion m3/year
Length:	200 km
Diameter:	24 inches
Maximum WD:	2,160 meters
Investment:	€ 900 million
Workforce:	Over 2,000 people will be involved in the construction phase

What now…

Photo: Geir Endal

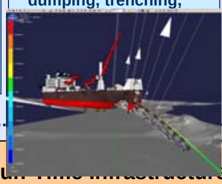
SIMLA.INSTALLATION

On board monitoring, analysis and decision support during offshore pipe lay operation

Status: DEMO'2000 Application (2007-02-21)

Lifecycle Approach

Field development	Design	Installation	Operation
• Concept development • Technology and concept evaluation • Environmental issues • Risk	• Routing/optimization • Seabed intervention • Free span evaluation • Installation analysis	• Interventions (rock dumping, trenching,	• Monitoring • Remaining fatigue life • Change in seabed topography • Change in operational conditions



High Level Architecture (HLA) / Ru... (RTI)

Storage and retrieval

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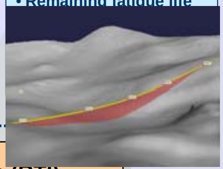


High Level Architecture (HLA) / Run-Time Infrastructure (RTI)

Storage and retrieval

Database

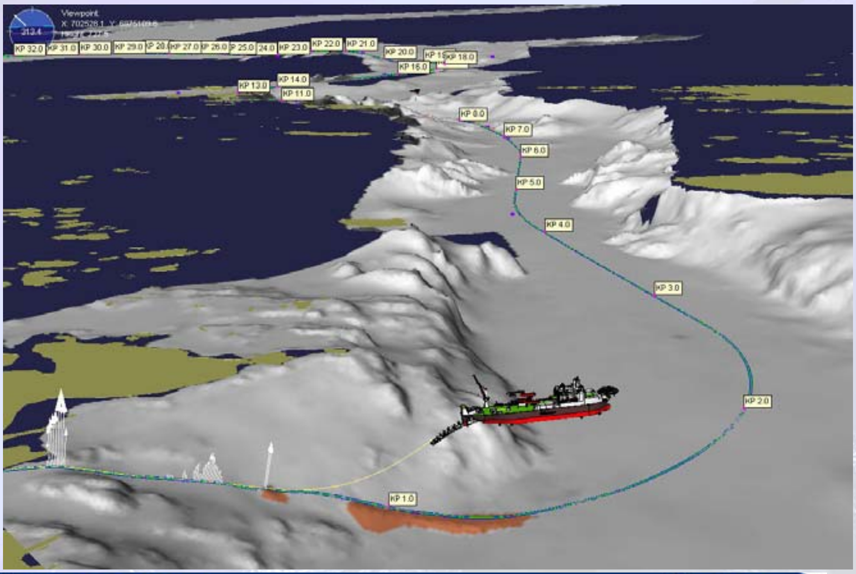
SIMLA.Installation - Main Objectives

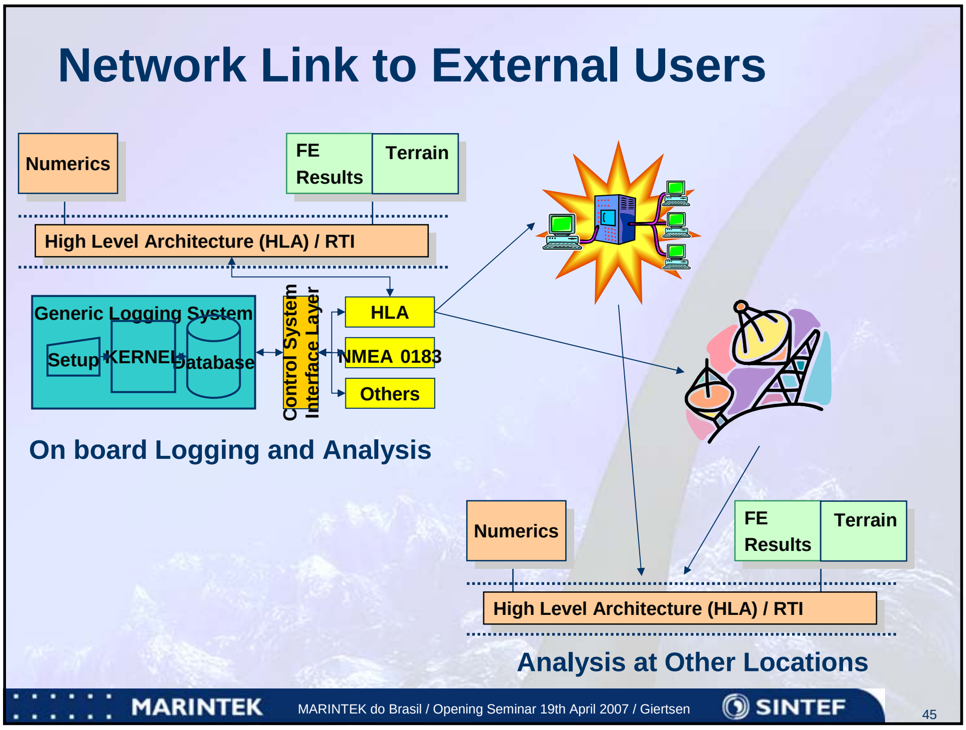
1. Generate, collect and store calculated key installation parameters from a selected set of design analyses (*as designed* datasets)
2. Generate, collect and store an equivalent set of key installation parameters from available on board control and monitoring systems (*as installed* datasets)
3. Create an on board decision support system by combining *as designed* datasets with real-time information
4. Calculate accumulated fatigue damage due to the installation, from the *as designed* and/or *as installed* datasets, as a function of pipeline route position
5. Apply *as installed* information as start-up condition for re-assessment analysis during operation

SIMLA.Installation - Potential

- On board 3D FEM analysis real-time, to support decisions related to specific events or emerging situations (bad weather + curves)
- Evaluation of laying stability, both for the current position and as forecast for the next section of the as-designed pipe route
- Generation of the As-built deliverable in a direct reusable form, also including key parameters from real-time 3D FEM analysis
- Connect via satellite link from onshore control rooms, and view the whole operation, including 3D FEM results, positions of supporting vessels, ROV's, etc
- For familiarization/HAZID/HAZOP, produce a complete 3D scenario (including 3D FEM results, laying stability evaluation, etc) of the installation process prior to the actual offshore operation
- For de-briefing, play back the installation process from the As-built log
- Based on the As-built log, calculate the accumulated fatigue damage due to installation, store it as a function of pipe route position and apply it as startup condition for fatigue assessment of critical areas during operation
- Assessment of on-bottom stability during operation
- Assessment of upheaval buckling and snaking during operation

On board monitoring, analysis and decision support during offshore pipe lay operation




Network Link to External Users
Numerics
FE Results
Terrain
High Level Architecture (HLA) / RTI
Generic Logging System
Setup
KERNEL
Database
Control System Interface Layer
HLA
NMEA 0183
Others
On board Logging and Analysis
Numerics
FE Results
Terrain
High Level Architecture (HLA) / RTI
Analysis at Other Locations
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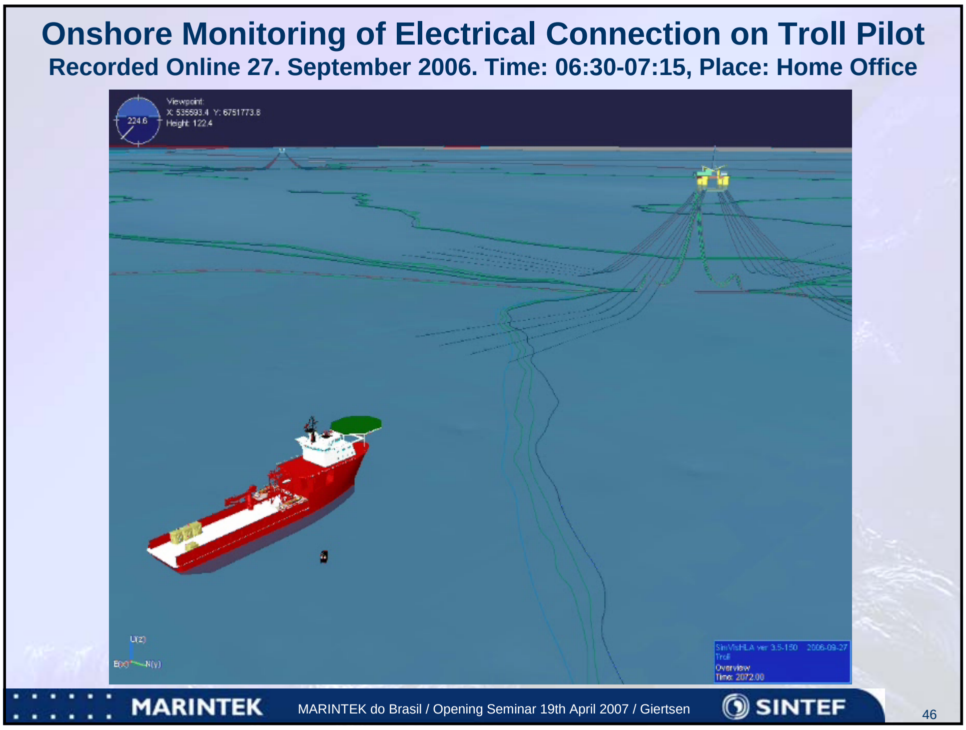
Onshore Monitoring of Electrical Connection on Troll Pilot
Recorded Online 27. September 2006. Time: 06:30-07:15, Place: Home Office
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