PRINCIPIA

IFP Energies nouvelles

# DeepLines™

## Offshore Structures FEA Software

*Rev.01 - September 2016*

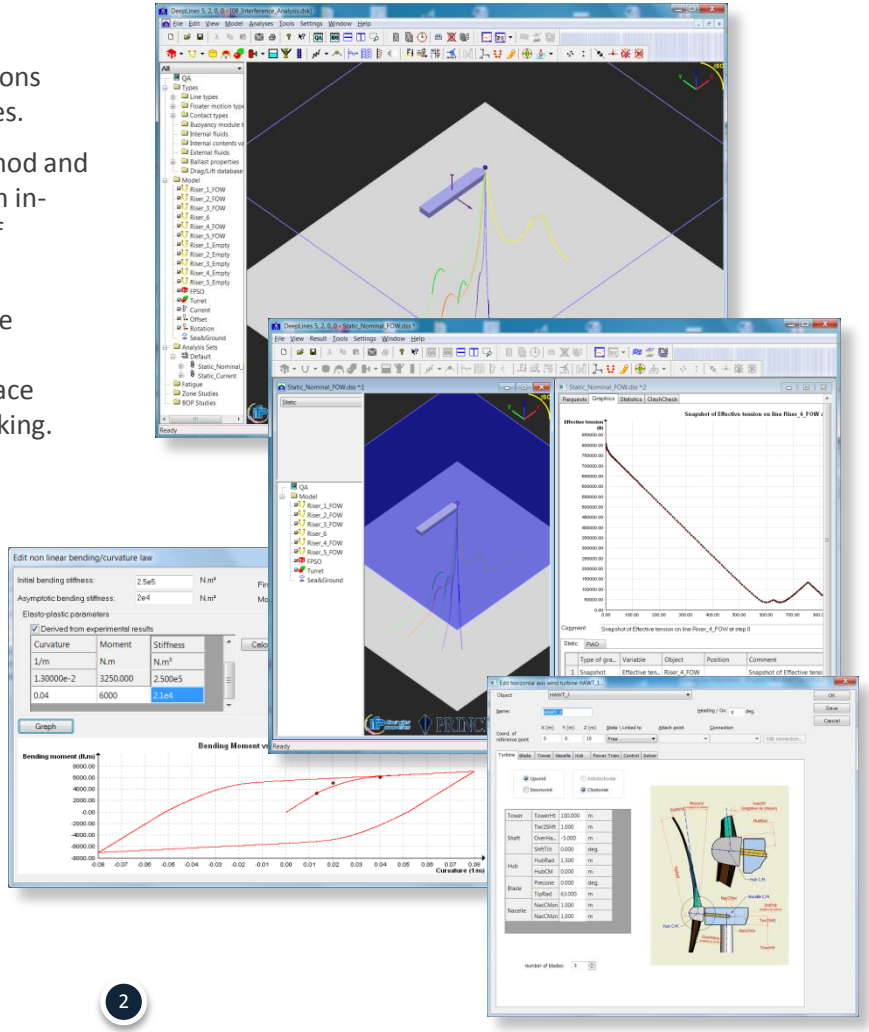
# Overview

## Overview

DeepLines™ is part of the marine software solutions developed by Principia and IFP Energies Nouvelles.

DeepLines™ is based on the finite elements method and forms an integrated software solution to perform in-place and installation analyses of a wide range of offshore structures.

The software package comprises a powerful finite elements engine featuring advanced modeling capabilities and an intuitive graphical user interface offering optimum productivity through multi-tasking.




## Key applications

- All types of slender offshore structures
- Flexible and steel risers
- Power cables and umbilical
- Pipelines
- Mooring systems
- Towed systems
- Renewable energy systems
- Marine operations

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# Applications


- Light and heavy lifts
- Riser and pipeline installation
- Deployment of subsea equipment
- Offshore crane operations
- Jacket launch and upending
- LNG marine loading arms
- Float-over deck installation

- Riser configuration setup
- ULS and ALS extreme analysis
- Fatigue damage along steel pipes
- Interference analysis
- VIV, VIM and VIR analyses
- Derivation of interface loads
- Advanced modelling of drilling risers with conductor pipe and casing

- Floating and fixed offshore wind turbines
- Array and export cables configurations
- Offshore met masts
- Global analysis of OTEC and SWAC systems
- Wave energy converters

- S-lay, J-lay and Rentis lay simulations
- Pipe sub-surface and surface tow
- Free-span identification and VIV analysis
- Thermal expansion, lateral buckling & pipe-walking
- Dynamic on-bottom stability
- Design of rigid base jumpers

- Pipeline and hybrid riser tower tow
- Seismic arrays
- Towed submarine defense antenna systems

- Fully coupled dynamic analysis
- Quasi-dynamic analysis
- ULS and ALS extreme analyses
- T-T fatigue damage analysis
- Out-of-plane bending (OPB) fatigue

# Key **features**

## Finite elements

- State-of-the-art nonlinear beam element formulation accounting for coupled axial/bending/torsion effects
- Specifically developed to handle large displacements
- Includes 6 DOF beam, 3 DOF bar and 3 DOF cable elements
- Complete control of 6 DOFs boundary conditions which may be changed during simulation (e.g. connection & disconnection)
- Non-linear bending stiffness with hysteresis effect to model unbounded flexible pipes and power cables
- Tapered joints and integrated bend stiffeners
- Winch lines with user controlled pay-in/out rate
- Multi-linear stiffness for risers and special bar elements to model synthetic ropes
- Linear and non-linear flexible joints connections for steel riser connections
- Spring components with linear and non-linear stiffness and damping
- Pulley components for loads transfer during installation operations
- Partially submerged lines account for non-linear hydrostatics

## Dynamic analysis

- Advanced implicit time-domain integration scheme for dynamic analyses
- Frequency-domain dynamic analysis can be used to perform screening studies and fatigue analysis
- Fully-coupled analysis of floating vessels, risers and mooring legs available both within time-domain and frequency-domain analyses (including low frequency vessel response)
- Quasi-dynamic modelling approach for mooring legs
- Hydro-aero-servo elastic coupling for wind turbines

## Line contact modelling

- Powerful and versatile line contact calculation algorithm
- External line to line contacts (e.g. clashing)
- Internal line to line contacts (e.g. PIP, guides, J-tubes)
- Line to any steady or moving rigid surface contact (e.g. seabed, bellmouth, mid-water arch)
- Static and hysteretic dynamic line-soil interaction stiffness
- Soil dynamic suction effect
- Advanced friction laws including berm effects
- P-y and T-z curves available to model soil foundations

# Key **features**

## Analyses types

- Non-linear static analysis based on Newton-Raphson solution procedure
- Quasi-static analysis with incremental loadings and displacements
- Time-domain dynamic analysis based on implicit Newmark's time-marching solution procedure
- Frequency domain dynamic analysis with regular or irregular waves (including low frequency response of moored vessels)
- Modal analysis of complete risers and mooring systems
- Design of drilling riser based on API RP 16Q
- Fully coupled analysis of vessels & lines
- Cross-flow VIV prediction model based on modal approach
- Dynamic cross-flow & in-line VIV prediction model based on wake oscillators
- VIV analysis  based on DNV-RP-F105
- Fatigue damage assessment through S-N and T-N curves
- Line to line clearance assessment

## Loadings

- Environmental loads including current, wind, regular and random waves
- Regular wave based on Airy, Stokes or Dean Stream theories
- Large set of conventional wave spectra available
- Advanced hydrodynamic loads formulation including Re dependent drag, drag and lift forces function of flow incidence
- Prescribed quasi-static and dynamic motion at nodes
- Prescribed point loads and distributed loads
- Steady and variable pressure, weight and temperature profiles along lines
- Dynamic slugs with variable velocity and density profiles
- Hydrodynamic wake effects on lines based on Huse or Blevins wake models
- Second order wave loads on vessels based on Newman assumption or full QTF for shallow water applications
- Hydrodynamic interactions between vessels

# Key **features**

## Post-processing

- Any type of static or dynamic output on lines and other model components required to check the integrity of the structure
- Interface loads at line ends expressed in the local coordinates system of the structure
- Summary sheets with statistics related to load cases matrices
- Linked statistics
- Export to Excel
- Derivation of RAO (e.g. motion, stress, tension) from both regular and random waves dynamic simulations
- DNV OS F201 & OS FA01 code checks available for steel risers and pipelines
- Dynamic results spectra and extrapolated extreme value statistics
- Hydrodynamic loads on vessels
- Static and dynamic clearance between lines
- Impact loads and energy
- Fatigue damage
- Export of modal analysis outputs to Shear7

## VIV analysis

- Predicts the dynamic response to short-term and long-term currents along with the resulting fatigue damage and drag amplification factor
- Steady cross-flow VIV model based on the modal superposition approach
- Dynamic cross-flow and in-line VIV models based on wake oscillators method
- Assessment of VIV along free-spans according to DNV-RP-F105 method is integrated

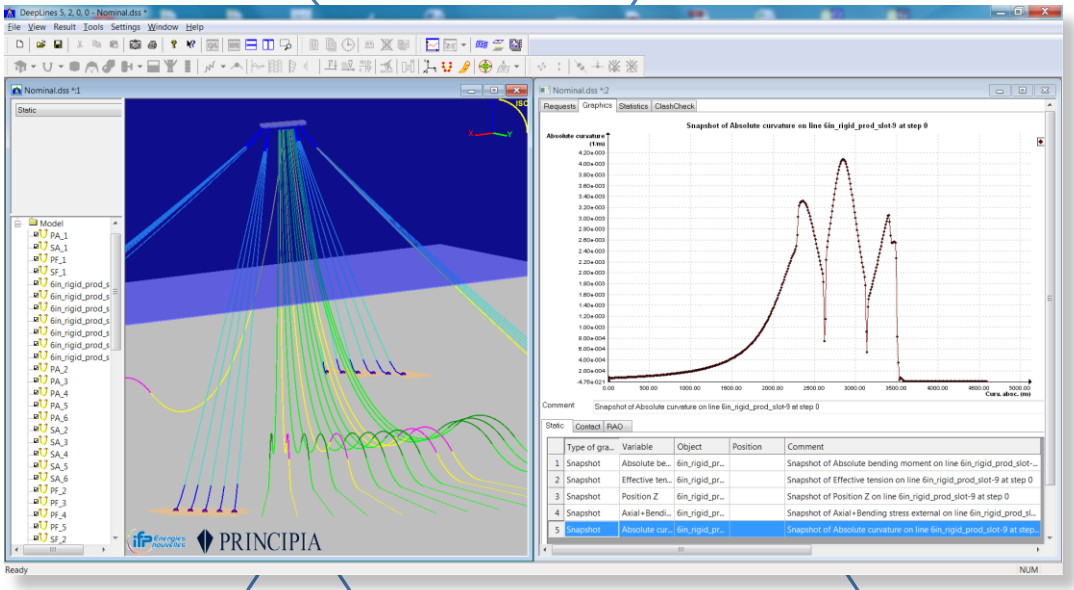
## Fatigue damage analysis

- Modular S-N and T-N curves libraries available
- Rain-flow damage counting method based on stress or tension time-series
- Spectral damage counting methods based on stress or tension RAO
- Direct spectral damage counting combined with dynamic frequency-domain simulations
- Tension-tension and bending-tension (OPB) fatigue damage for mooring chains
- Fatigue damage of Trelline® flexible hoses

# User **interface**

- Modular working environment
- Multiple windows GUI
- Unattended batch processing features with multi-tasking capabilities
- Comprehensive help system

- Wide range of structural model components
- Wide range of environmental loadings
- Designed to handle large set of load cases
- Copy/paste and import/export features are available for any model components




- Direct control of all components and loads from a unique model file
- Simple setup of complex models through standard and custom model components

- Displays animations and numerical outputs
- Video files export
- Export to Excel

- Large sets of static and dynamic outputs available
- Includes plots and statistics
- Fatigue analysis through spectral and RFC method

# Batch & **productivity**

Offshore engineering is continuously raising its standards thus also increasing the required number of analysis cases all of which need to be completed within challenging projects' schedules. Answering these needs implies enhancing automation of analyses setup and optimizing the use of computer capacity.

## Analyses sets

Any model may include several Analyses Sets which typically correspond to the load case matrices that need to be considered within the design. These Analyses Sets are based on series of environmental loads that may be conveniently defined within the Environment Sets components.

## Batch processing

The Batch Processing is designed to answer users demand and helping completing thousands of analysis cases at limited effort. The Batch Processing form is fully integrated into the GUI and is directly available from the Tools menu.

The form consists in a list of tasks to be performed, and includes controls to setup the list and run the tasks. Each task is defined through an input file and a job type which defines the type of command to be executed.

The batch processing facility may be used to perform tasks that go from analysis files setup to analysis results export to Excel.

Tasks such as fatigue analysis, zones study post-processing, export of results statistics, and clearance check analysis may also be included in the list of tasks.

The batch processing interface finally provides a better control over the analyses as it reports the current status of every tasks, indicating whether it is successfully completed, running or failed.

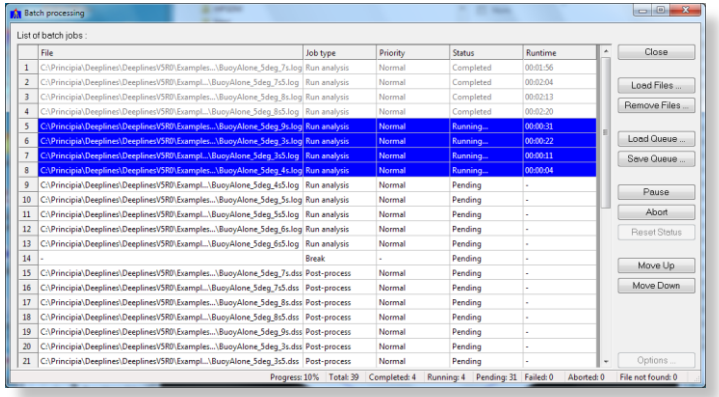
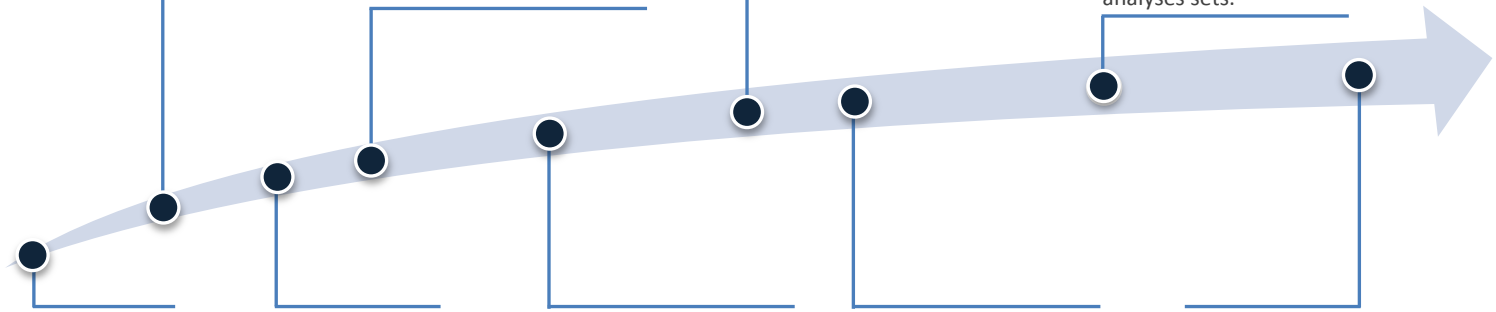



*Fig. View of the Batch processing data form*

## Multi-tasking

Multi-tasking is available through the Batch Processing form. Users may run up to 8 tasks concurrently and take advantage of multiple-cores processors capacities, still using a single license key.

# Development **history**



**1980: FLEXAN**

In-house program developed by IFPEN.

Featuring cable elements and regular waves.

**1985: FLEXAN D**

Development of first beam elements formulation at CISI Pétrole Services.

**1991: FLEXAN F**

Received certification from Bureau Veritas for flexible riser analysis.

Featuring beam elements with random waves.

**1995: FLEXAN G**

Extensively tested and used in Coflexip Stena Offshore.

Featuring updated beam elements formulation and implicit dynamic integration scheme developed at Ecole Centrale Paris.

**1998: DeepLines v1 series**

Based on ISYMOST™ graphical user interface.

Marketed by Principia.

**2000: DeepLines v2 series**

Received certification from Bureau Veritas for flexible riser analysis.

Featuring integrated bend stiffener model and mid-water arch component.

**2003: DeepLines v3 series**

Based on dedicated graphical user interface.

Featuring VIV analysis, fully coupled mooring analysis and advanced contact modelling.

**2007: DeepLines v4 series**

Featuring fatigue damage analysis and frequency domain analysis.

Enhanced batch capabilities and lines clearance processing tool.

Environment s sets and analyses sets.

**2011: DeepLines v5 series**

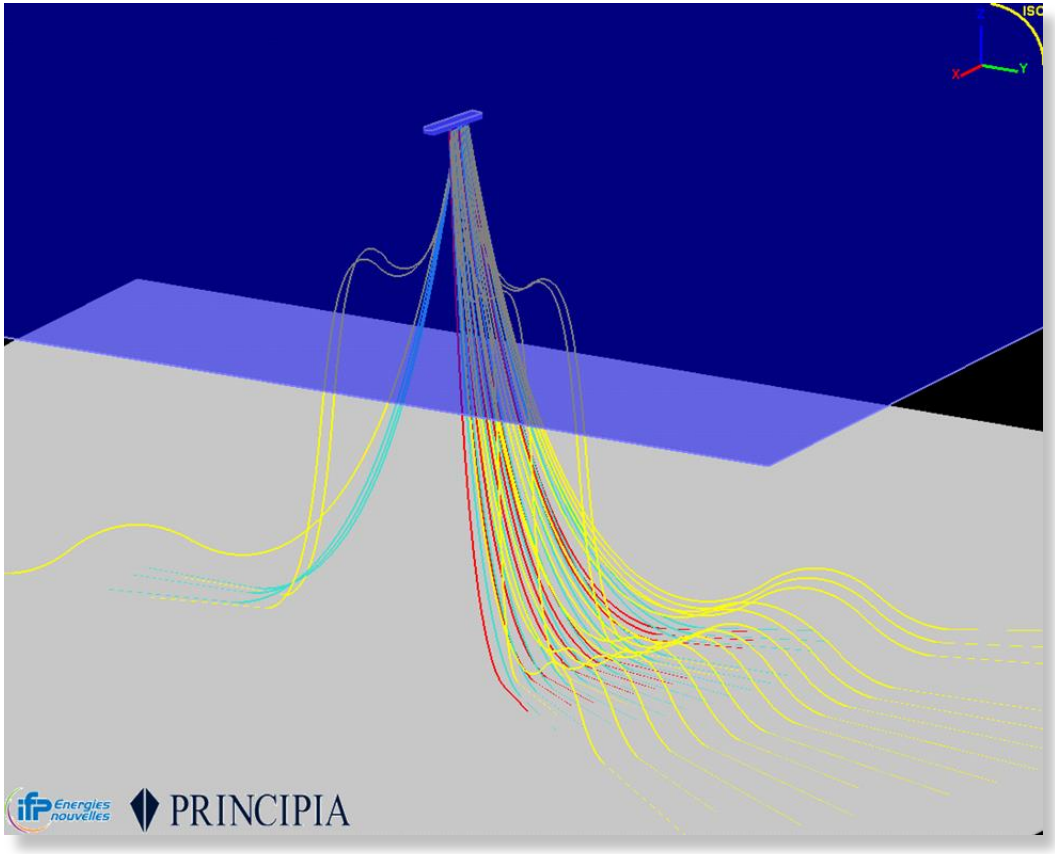
Enhanced GUI flexibility with Python scripts.

Offshore wind turbines.

Quasi-dynamic mooring analyses.

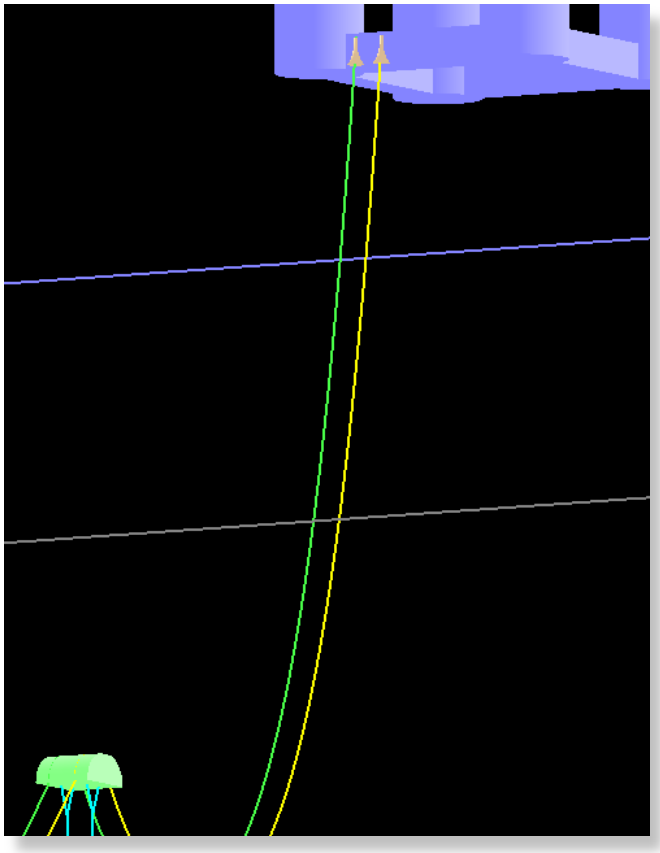
# Flexible & steel riser **applications**

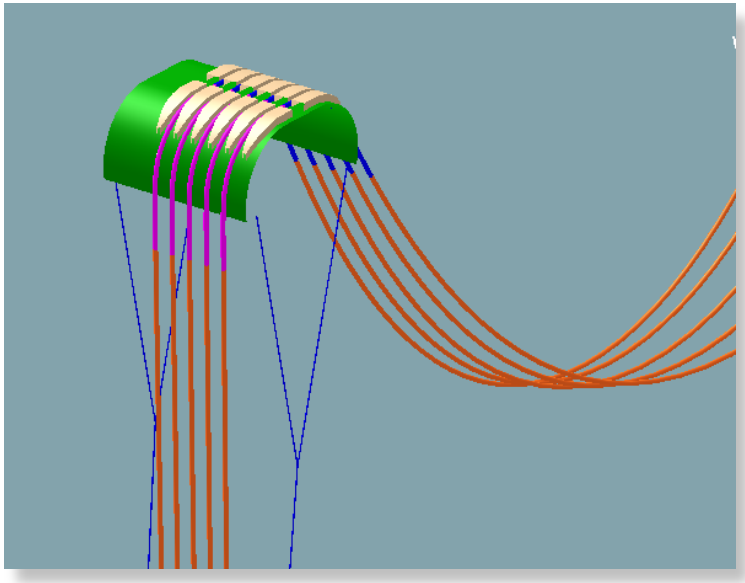
## Steel and flexible risers



# Flexible & steel riser **applications**

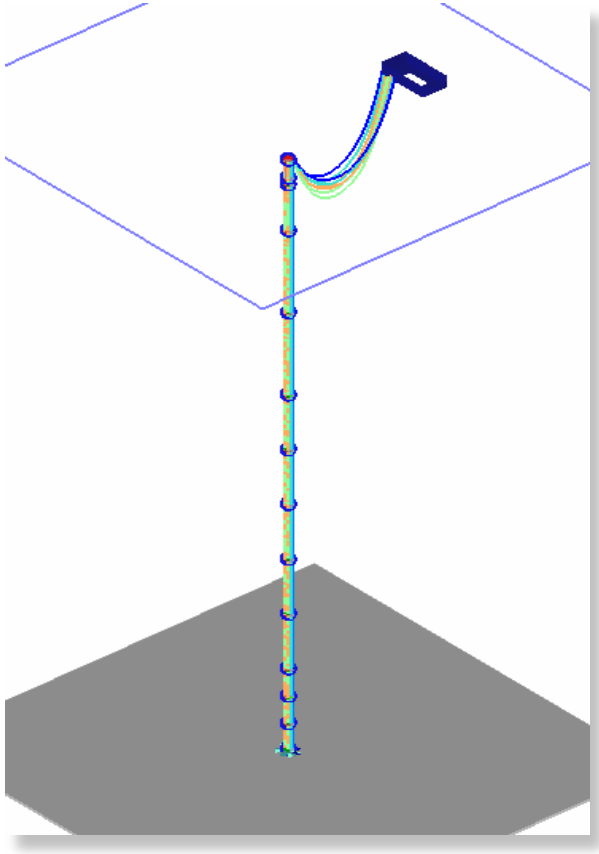
## Lazy-S flexible riser configurations

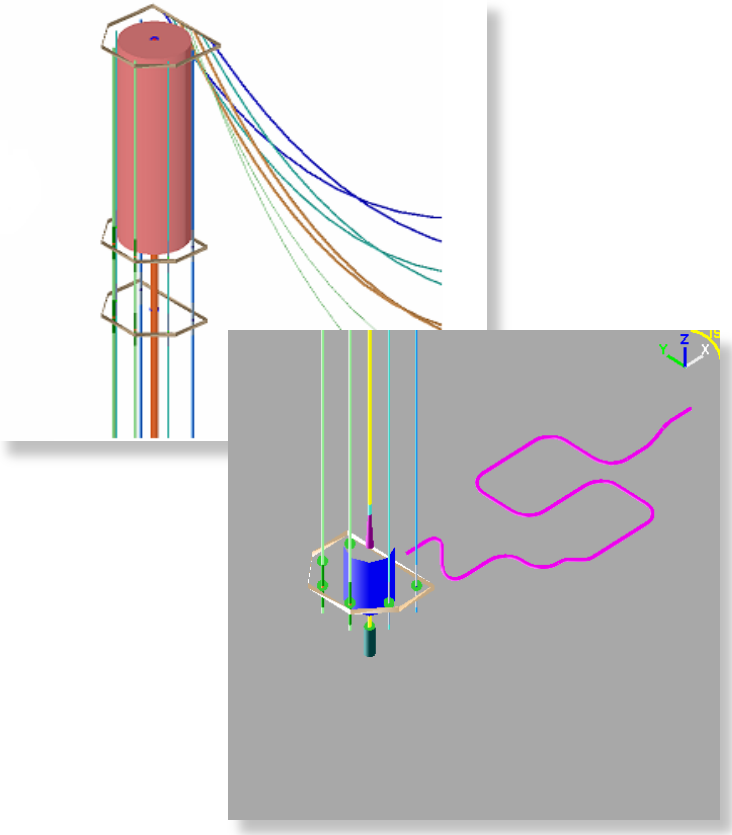




# Flexible & steel riser **applications**

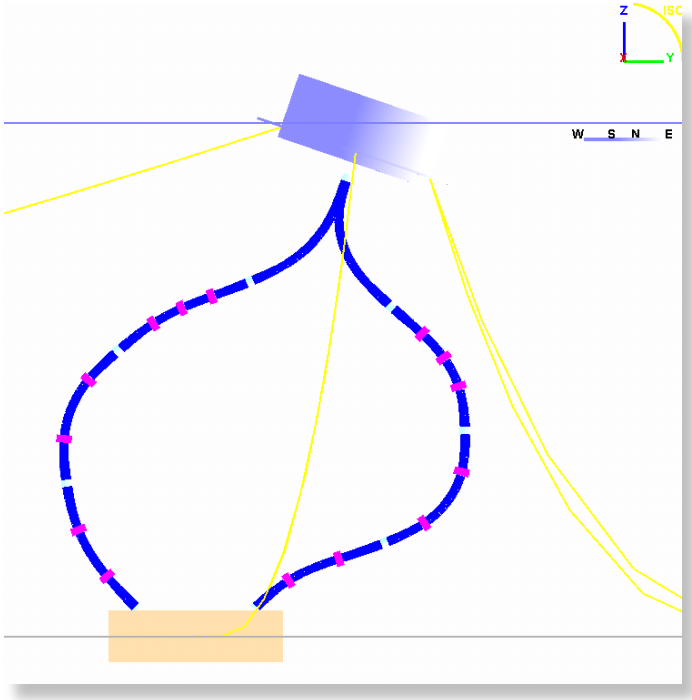
## Hybrid riser tower

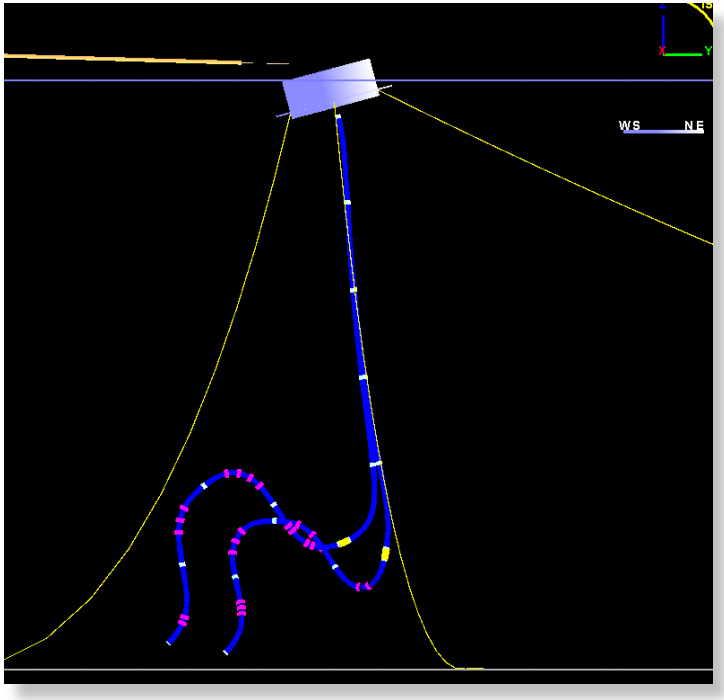




# Flexible & steel riser **applications**

## Loading terminals

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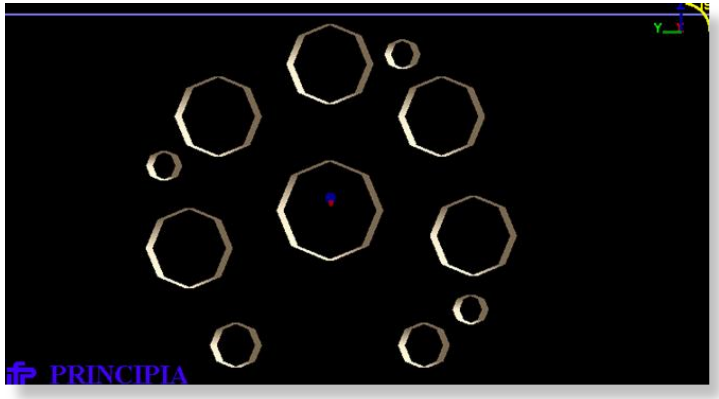
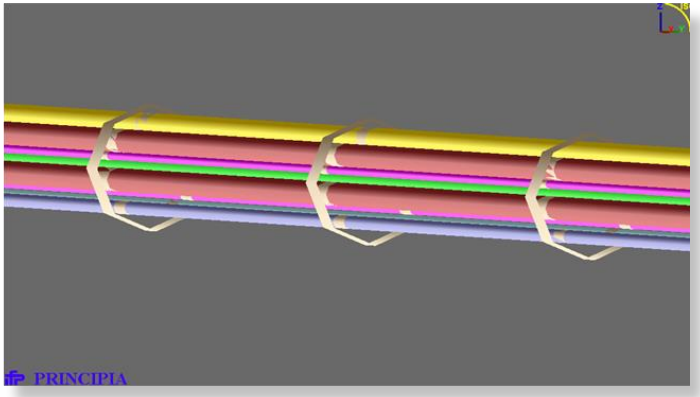
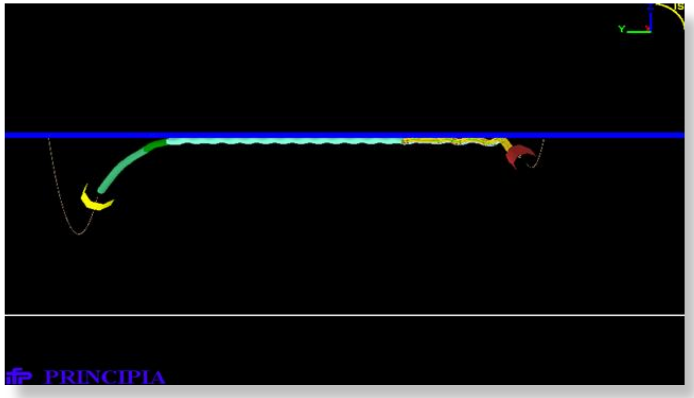
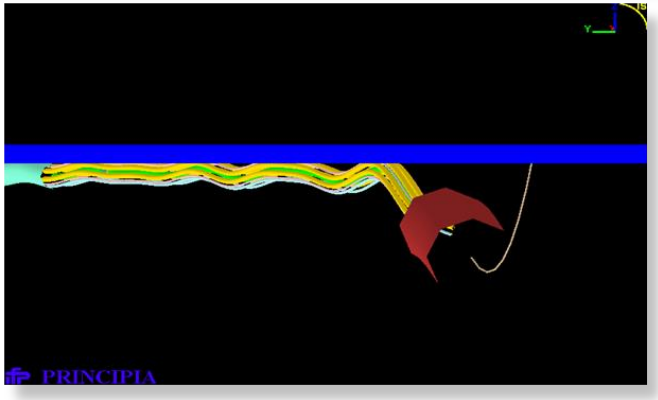
# Flexible & steel riser **applications**

## Hybrid riser tower bundle tow



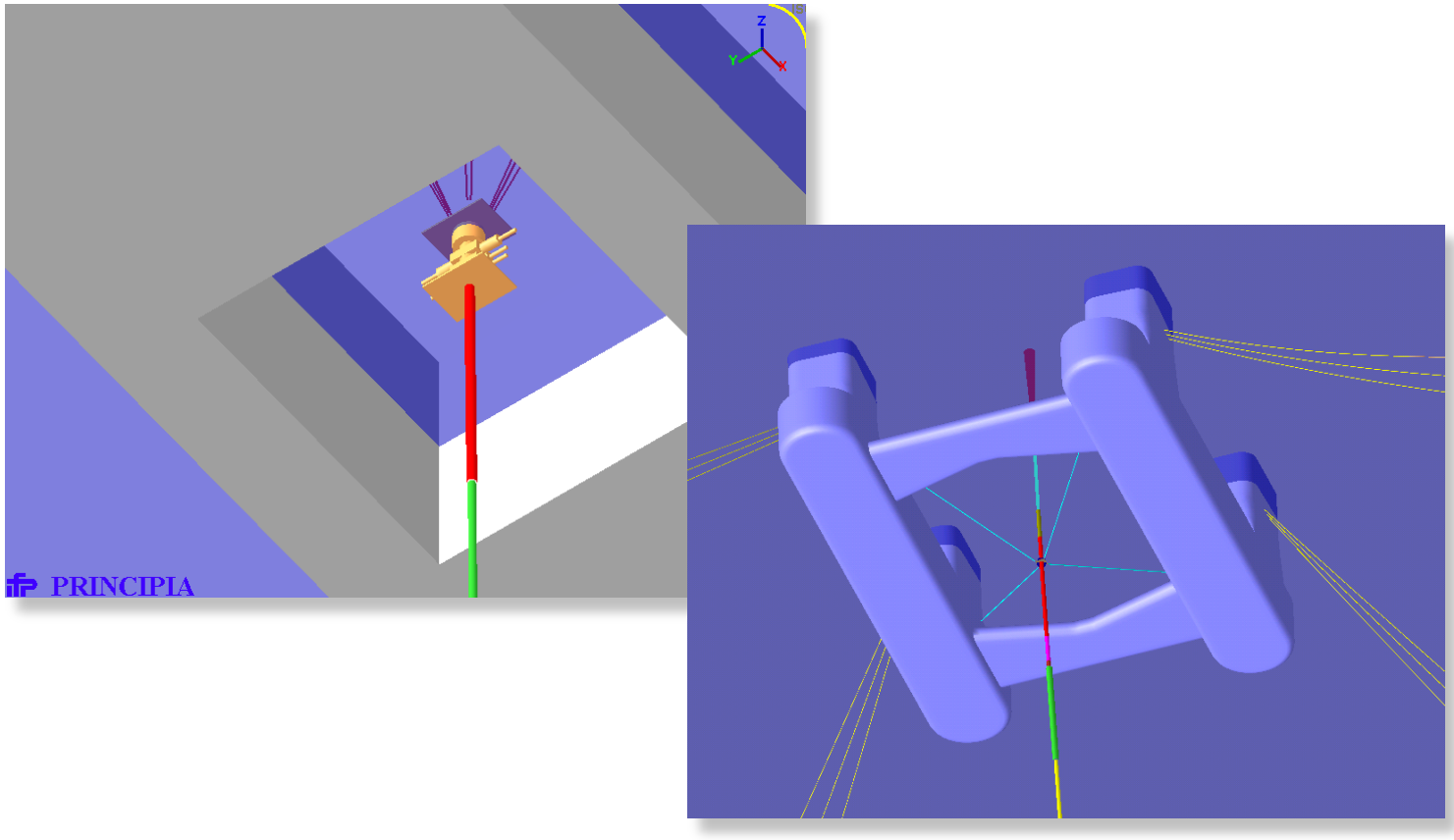



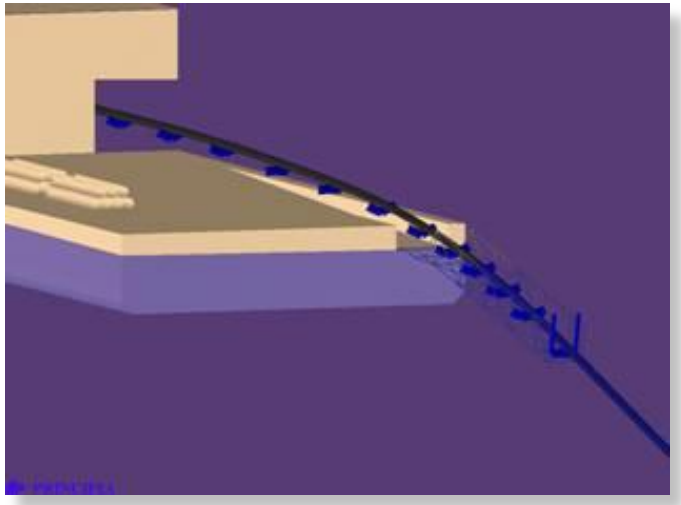
# Flexible & steel riser **applications**

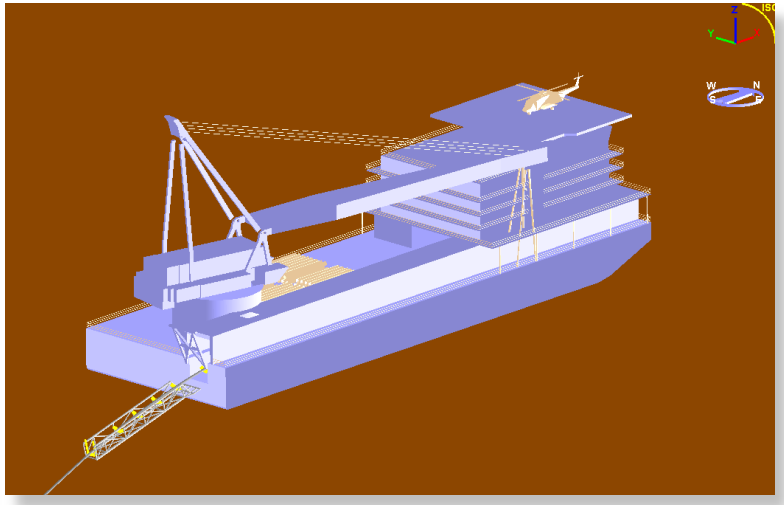
## Drilling risers

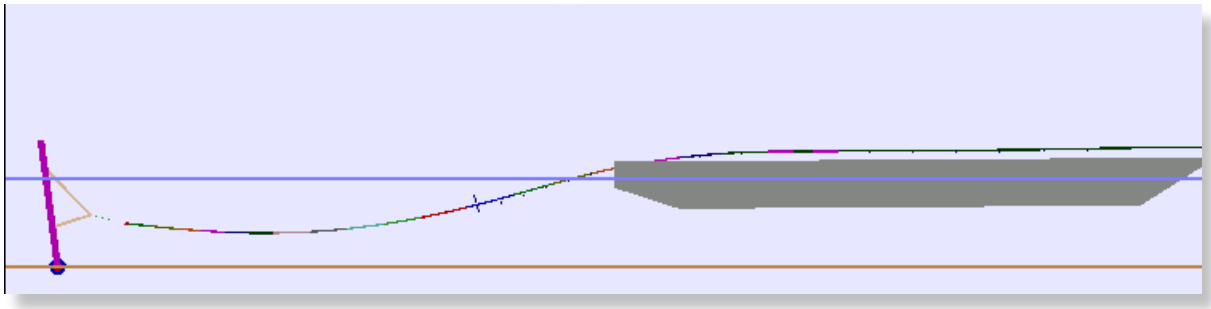


# Pipeline **applications**

## S-lay

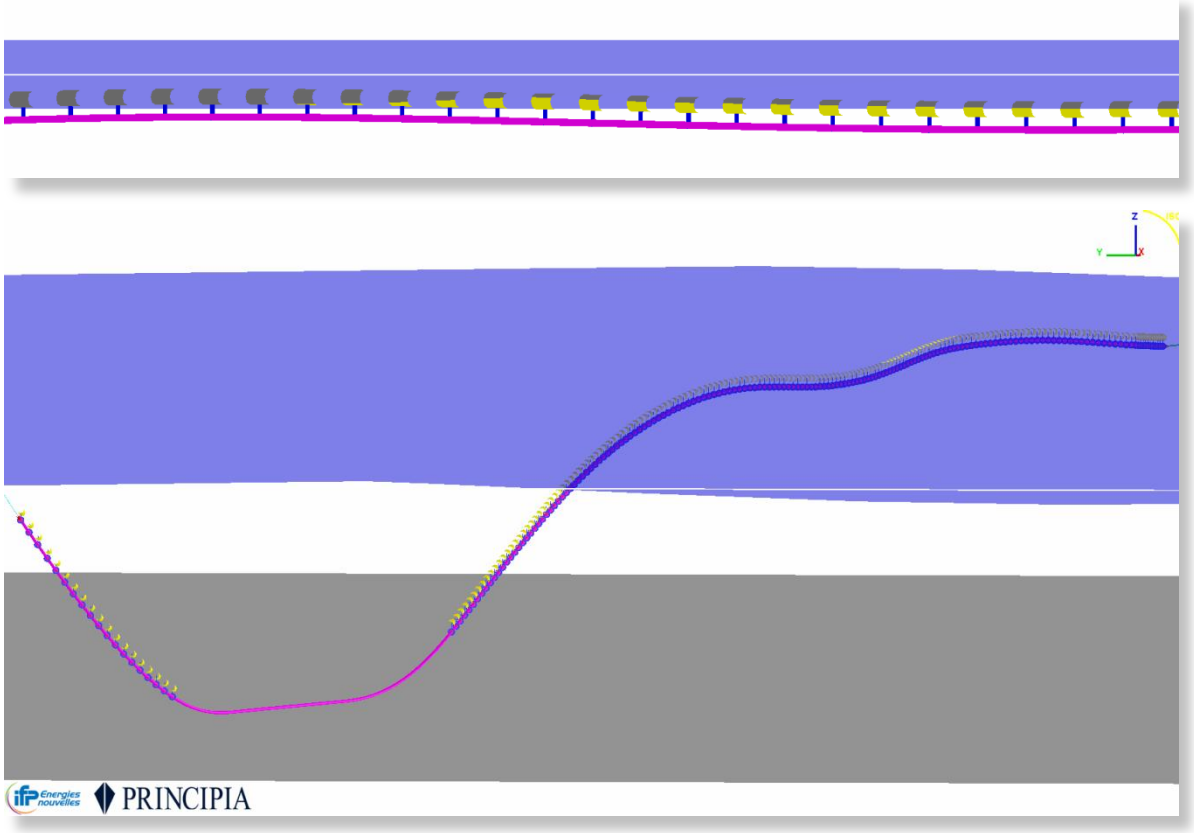






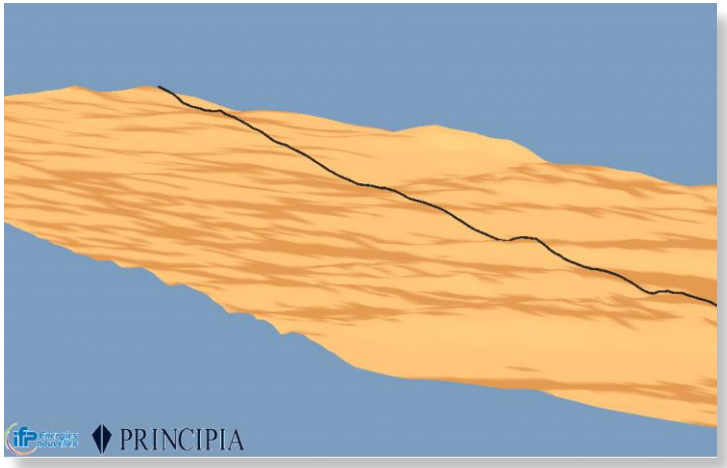
# Pipeline **applications**

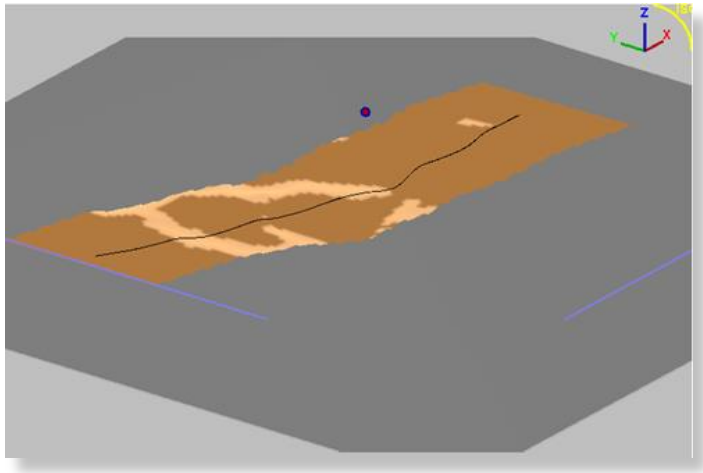
## On-surface tow (Rentis lay method)

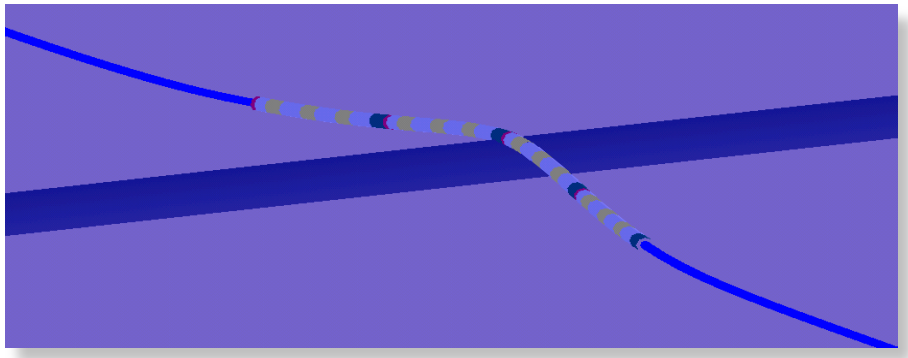


# Pipeline **applications**

## Cable free-span and 3D on-bottom stability

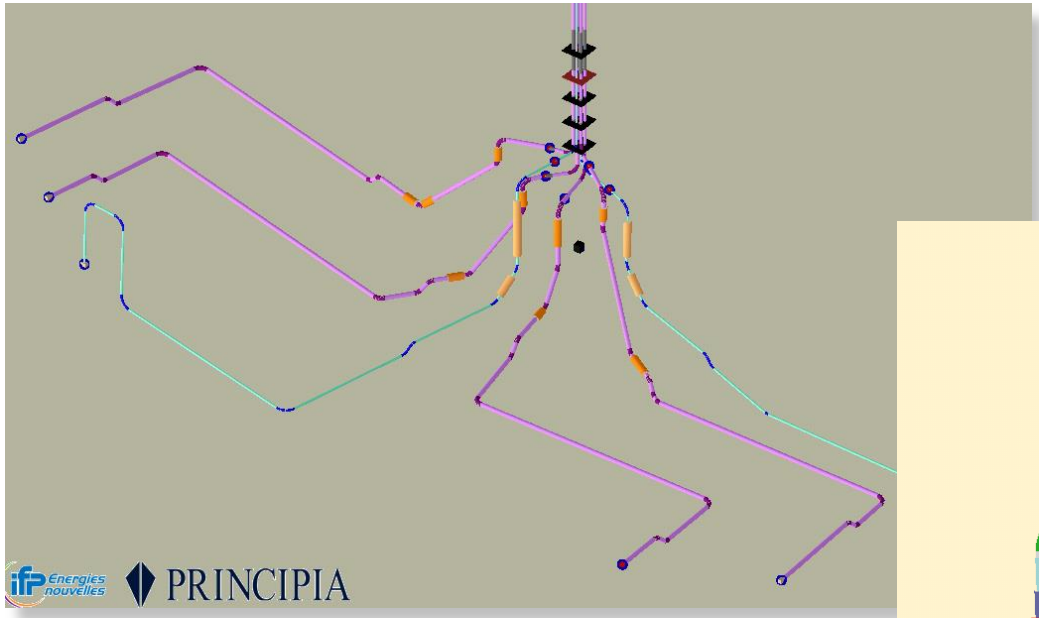


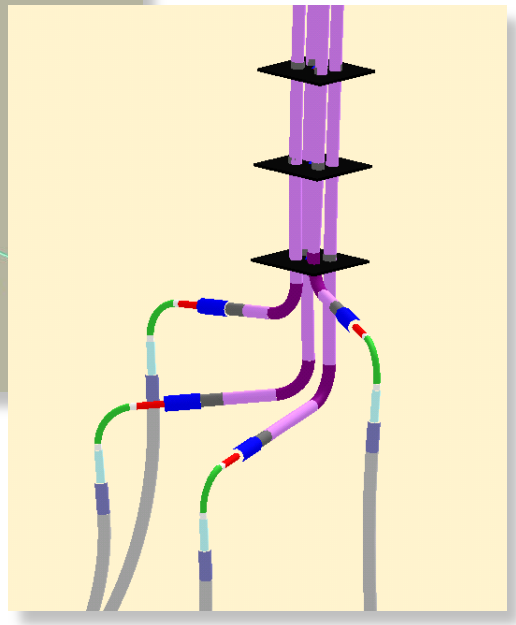





# Pipeline **applications**

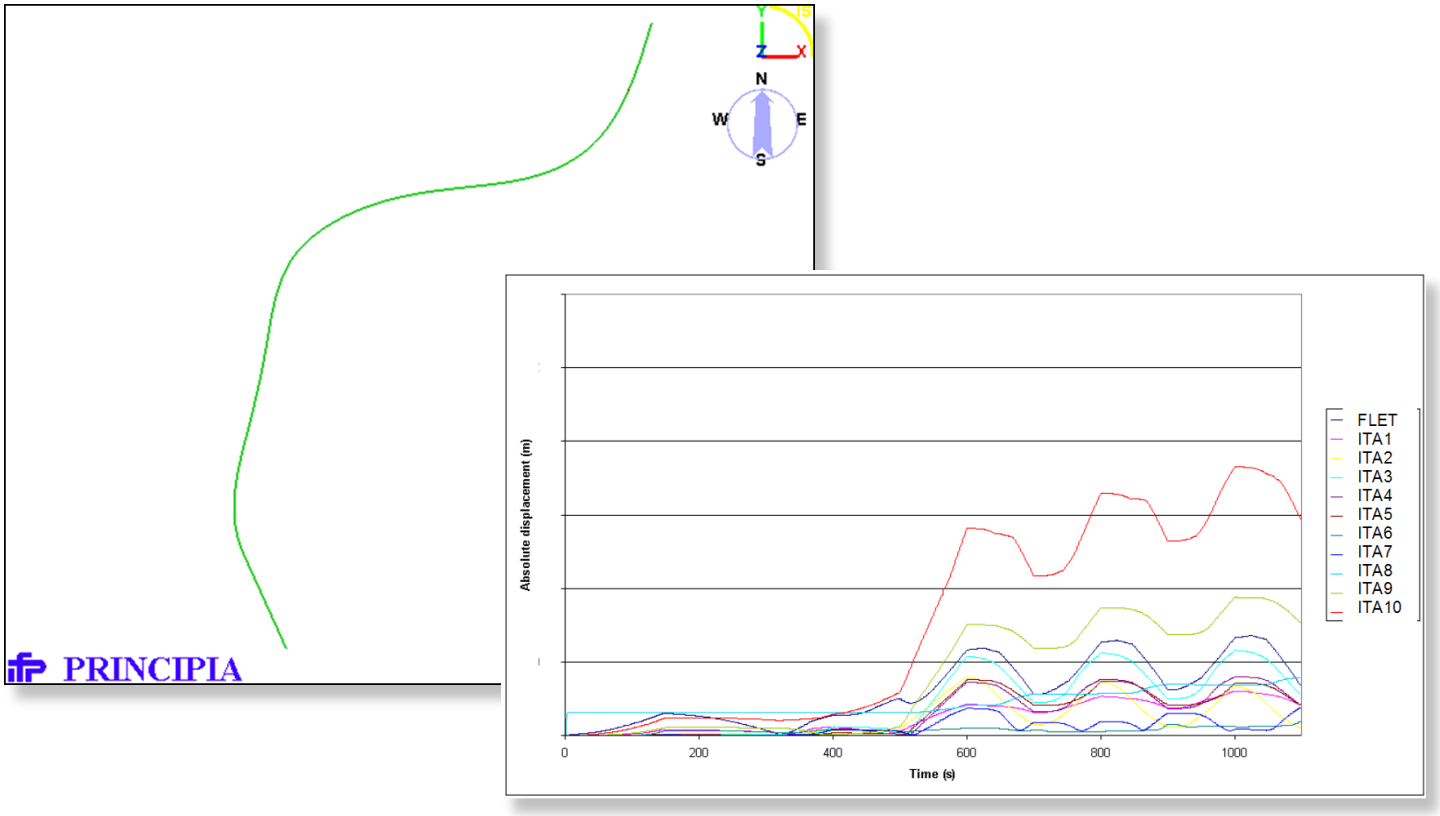
## Steel riser base jumpers



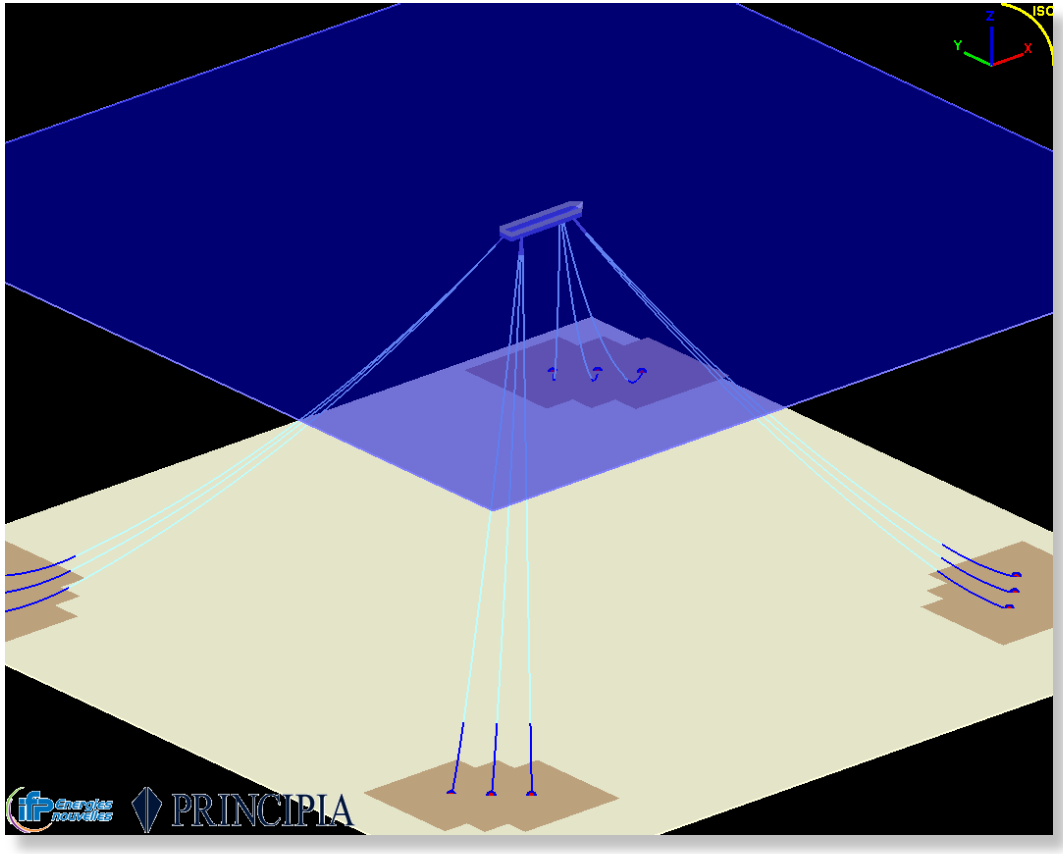
# Pipeline **applications**

## Lateral buckling and pipewalking



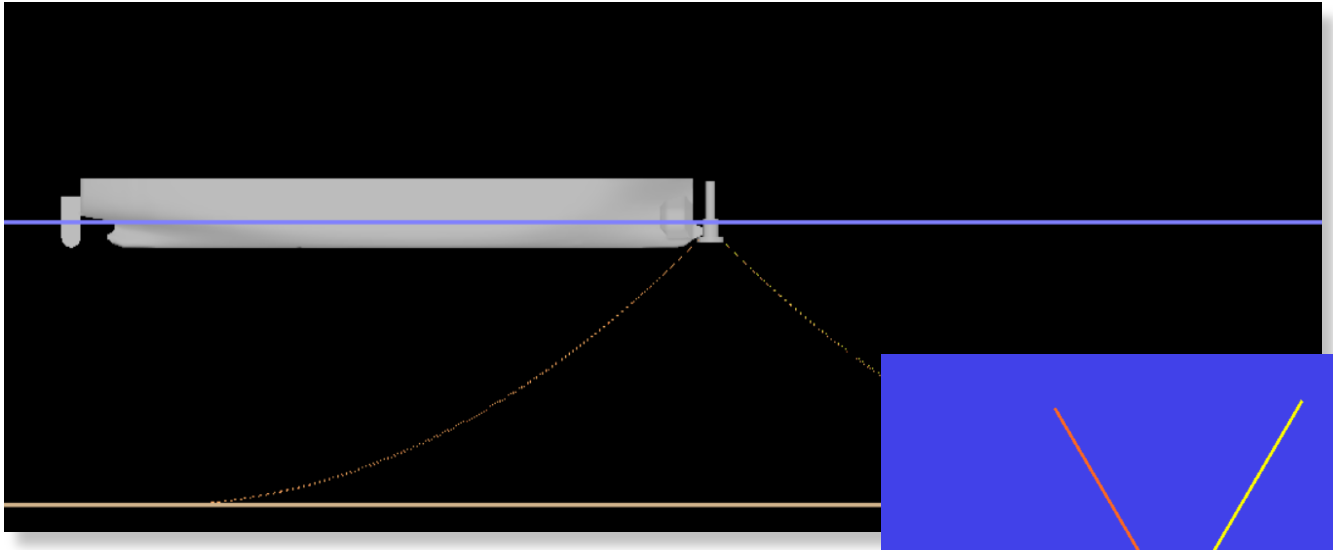
# Mooring systems **applications**

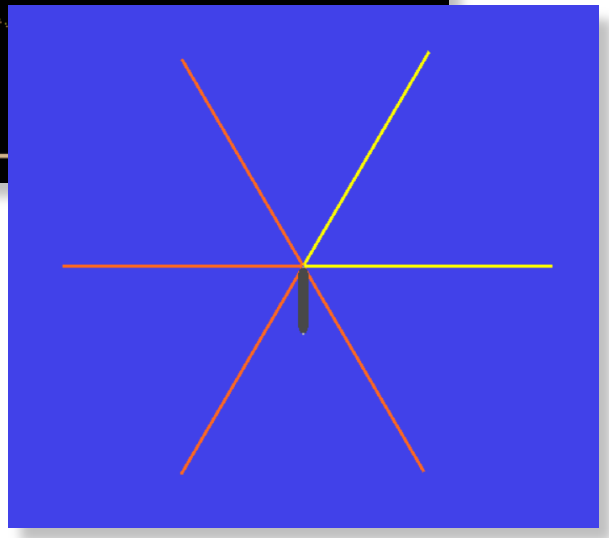
## Spread-moored FPSO



# Mooring systems **applications**

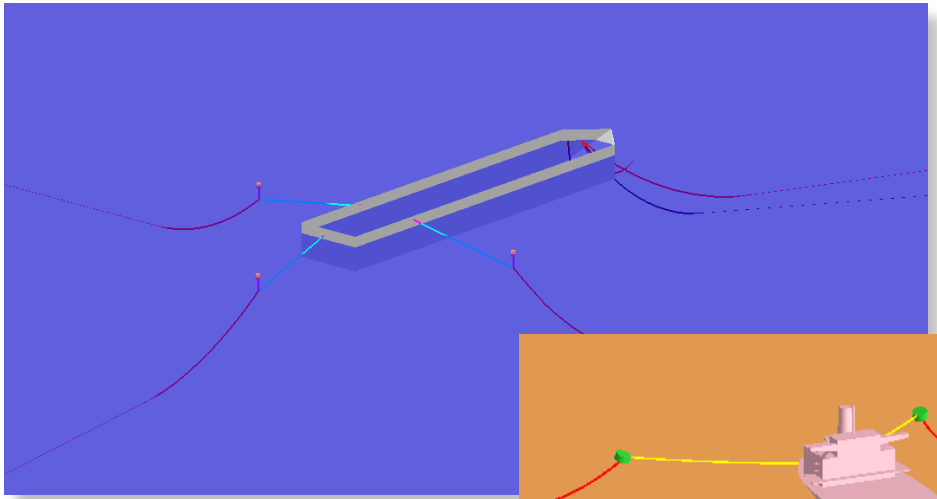
## Turret-moored FSRU

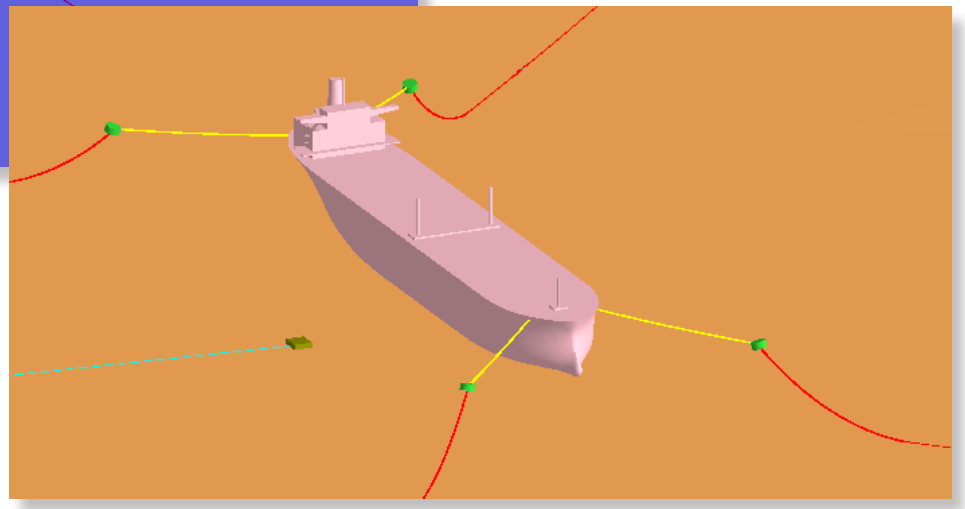




# Mooring systems **applications**

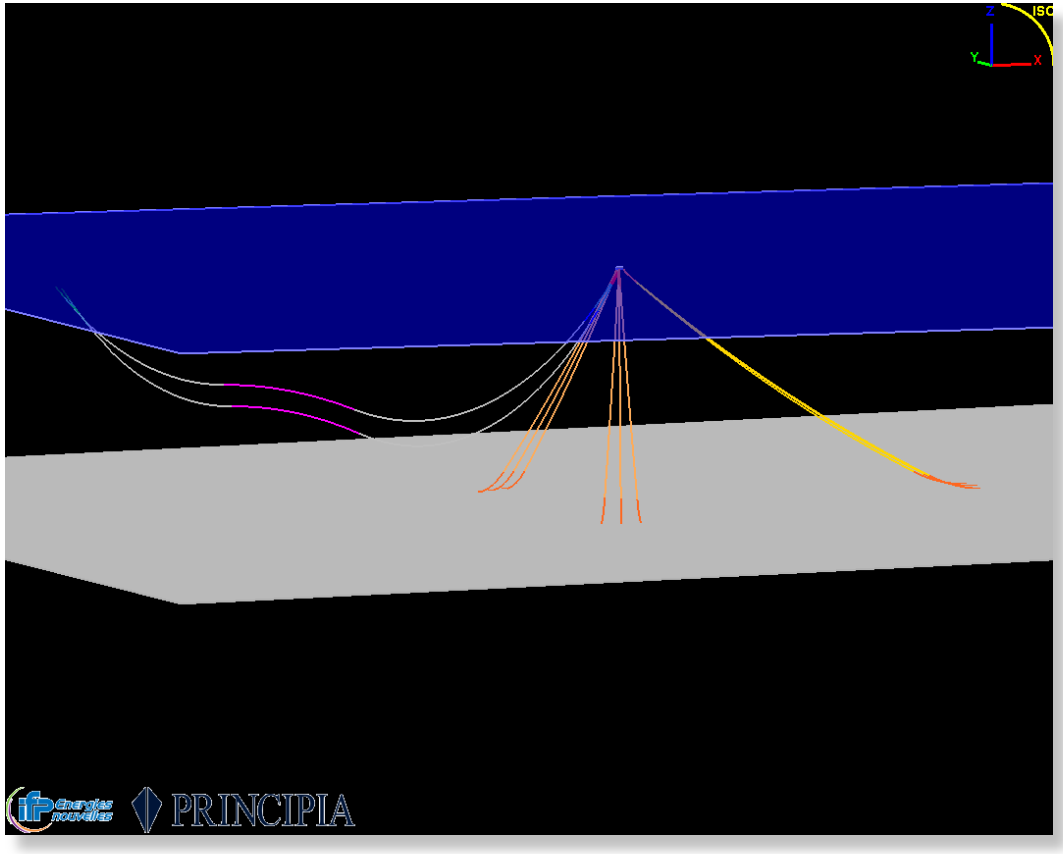
## Conventional buoy mooring terminals





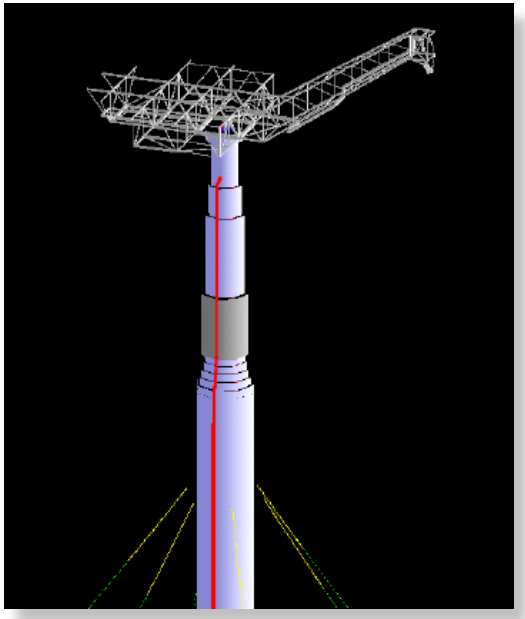
# Mooring systems **applications**

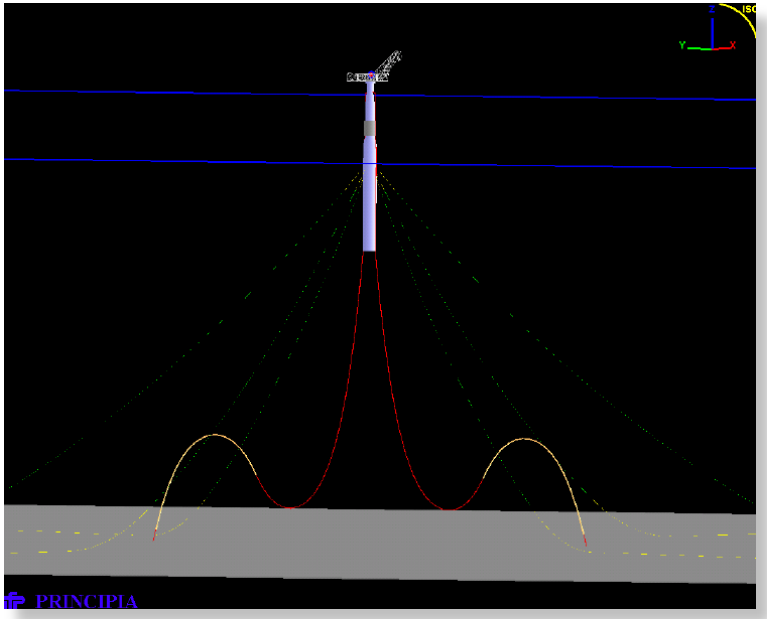
## Deepwater CALM buoy



# Mooring systems **applications**

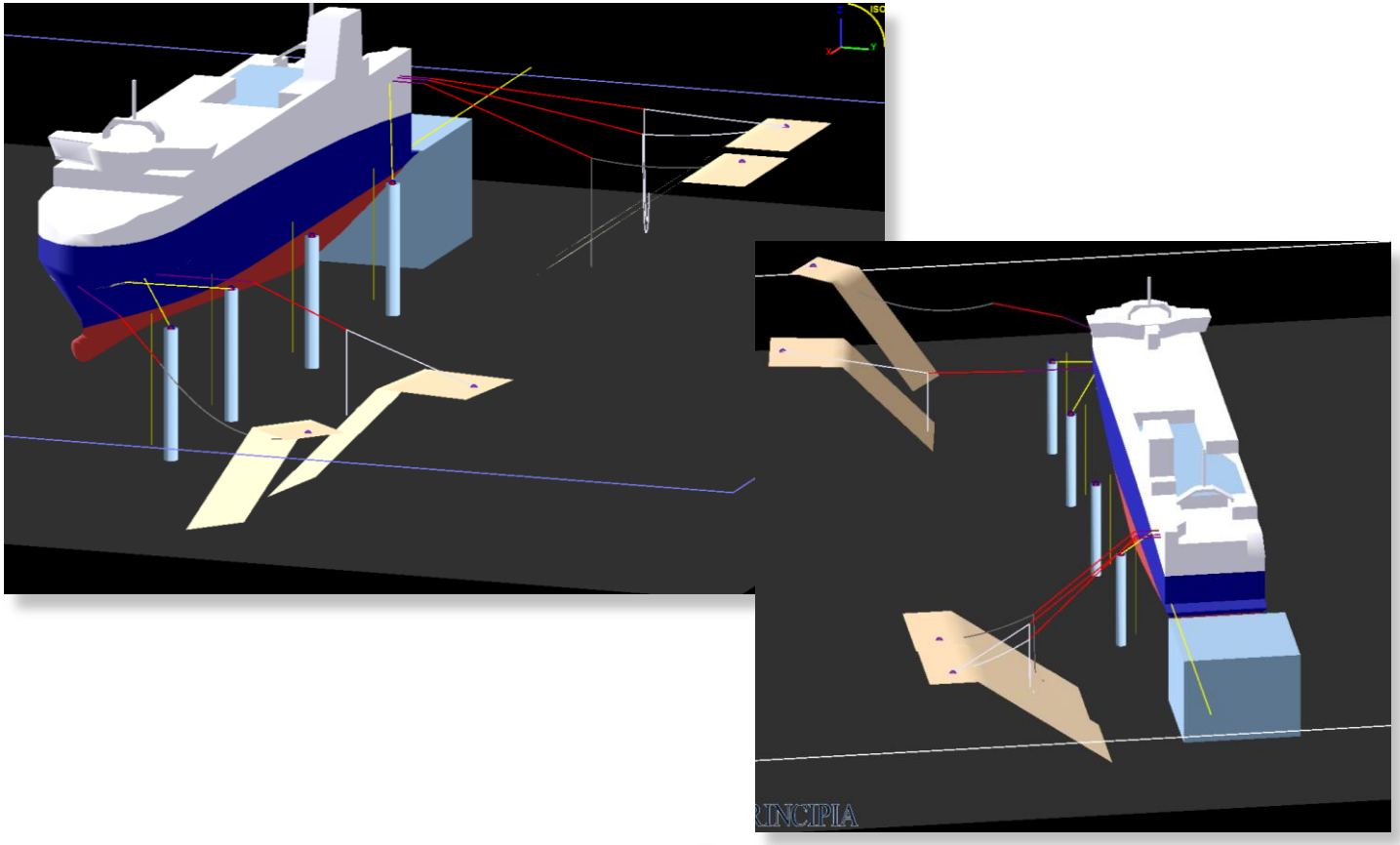
## Floating loading platform





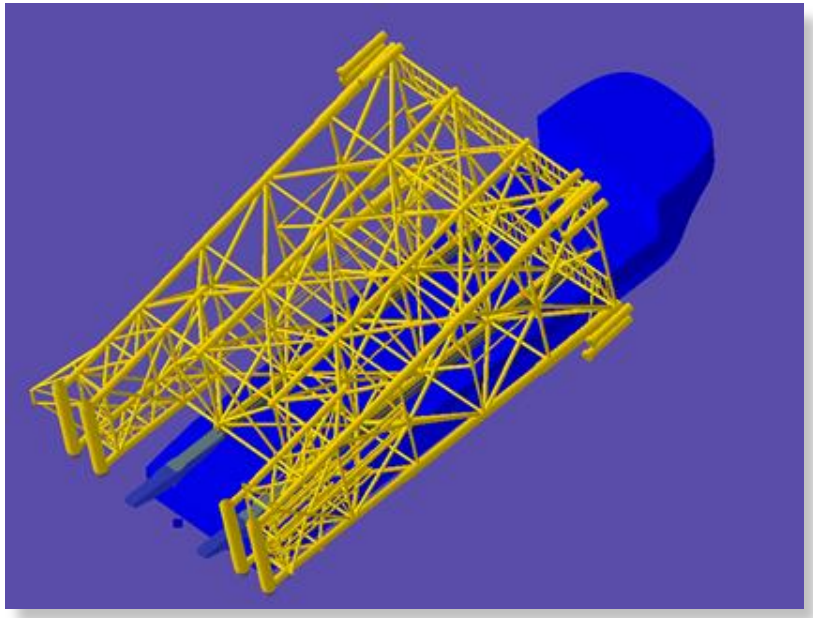
# Mooring systems **applications**

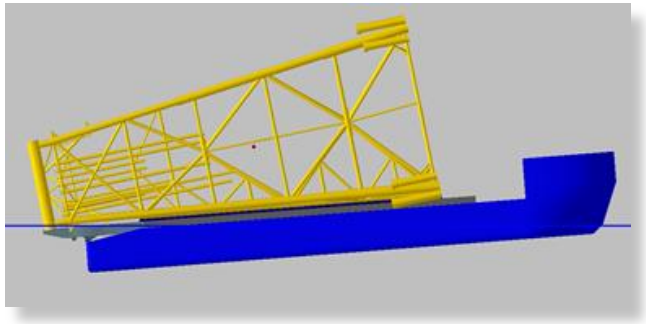
## Vessel berthing

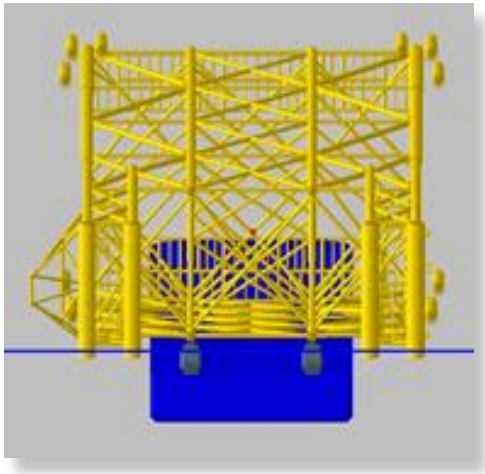


Marine operations **applications**

## Jacket launch

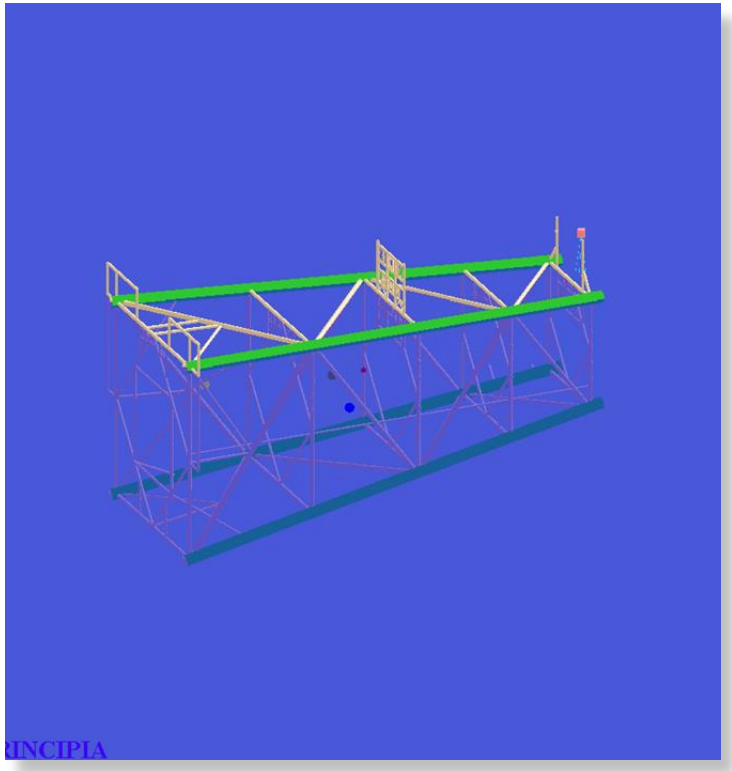


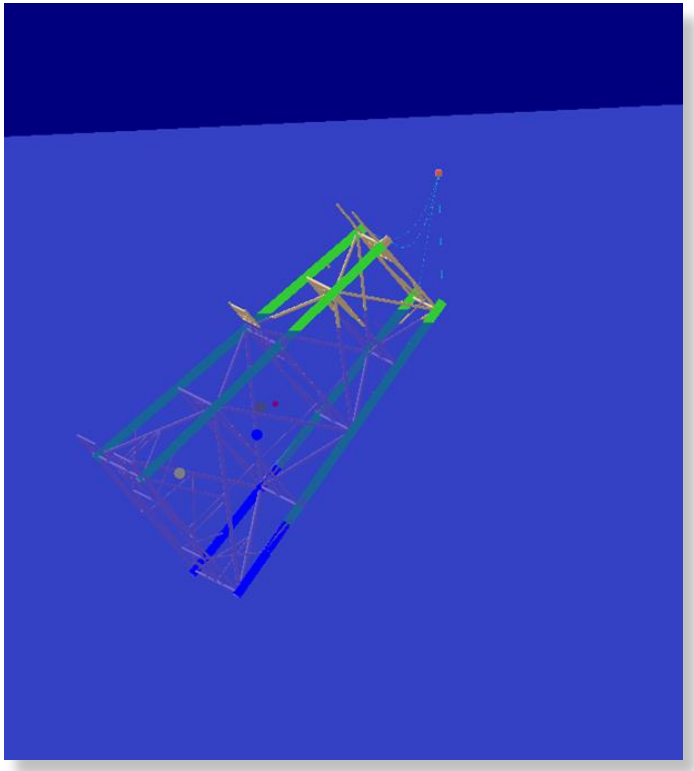




# Marine operations **applications**

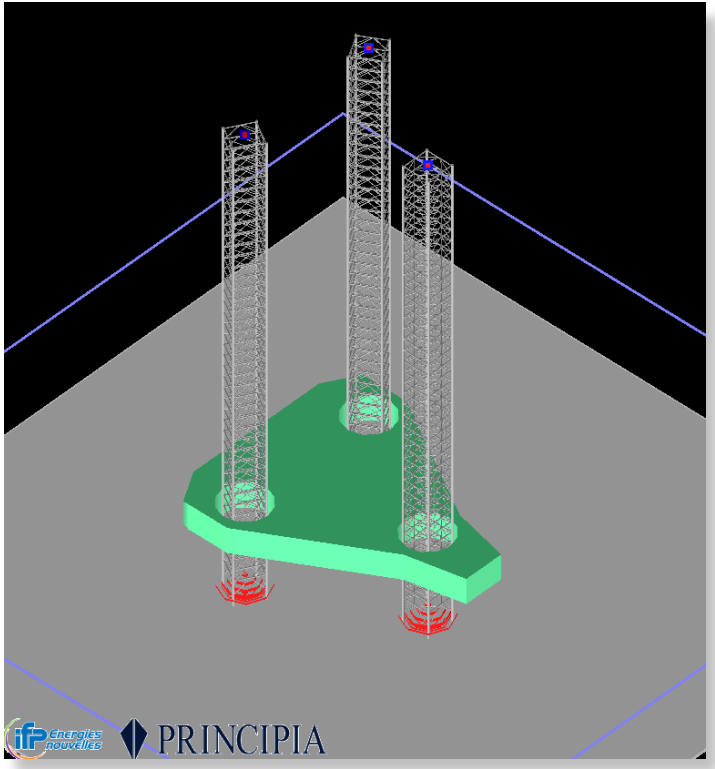
## Jacket upending

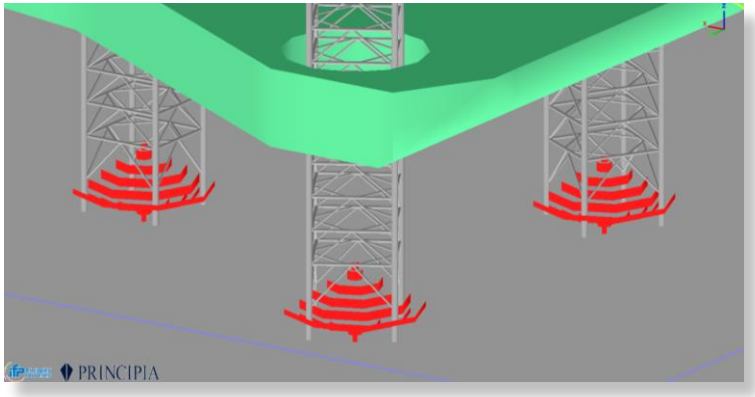


# Marine operations **applications**

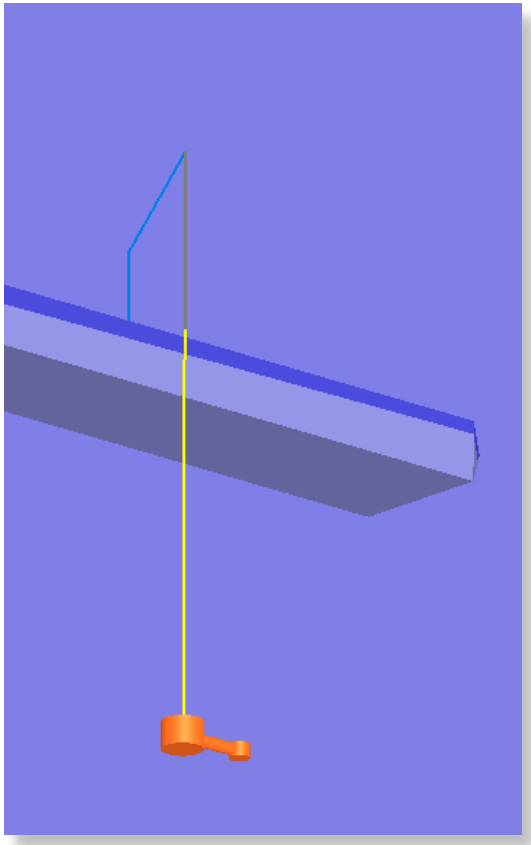
## Jack-up

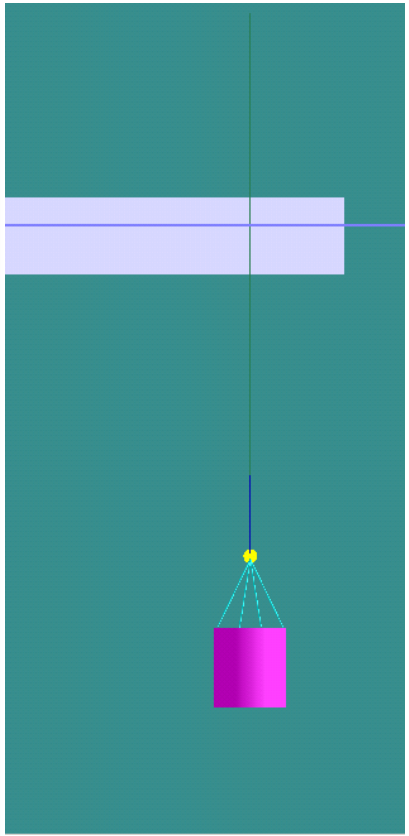


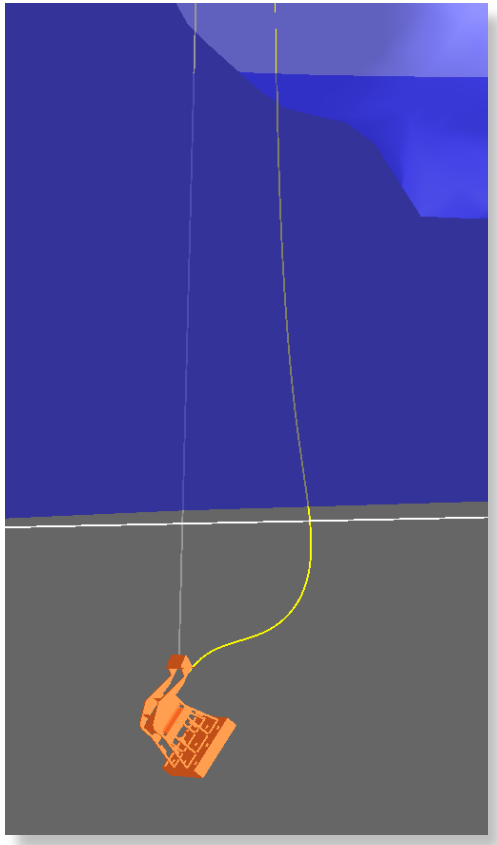



# Marine operations **applications**

## Offshore light lifts

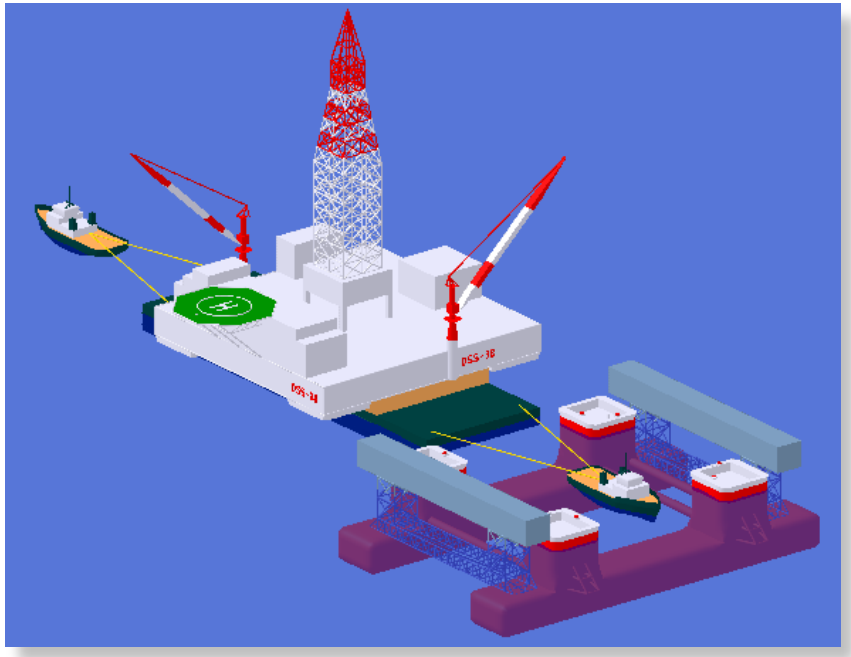


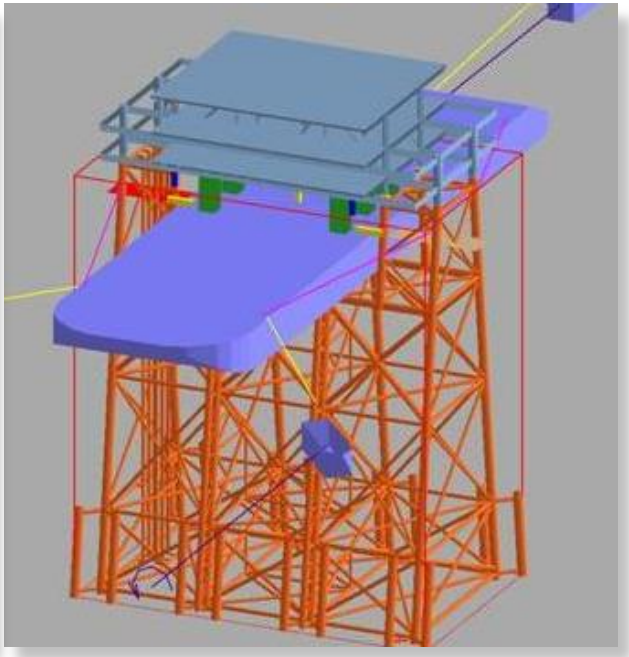




# Marine operations **applications**

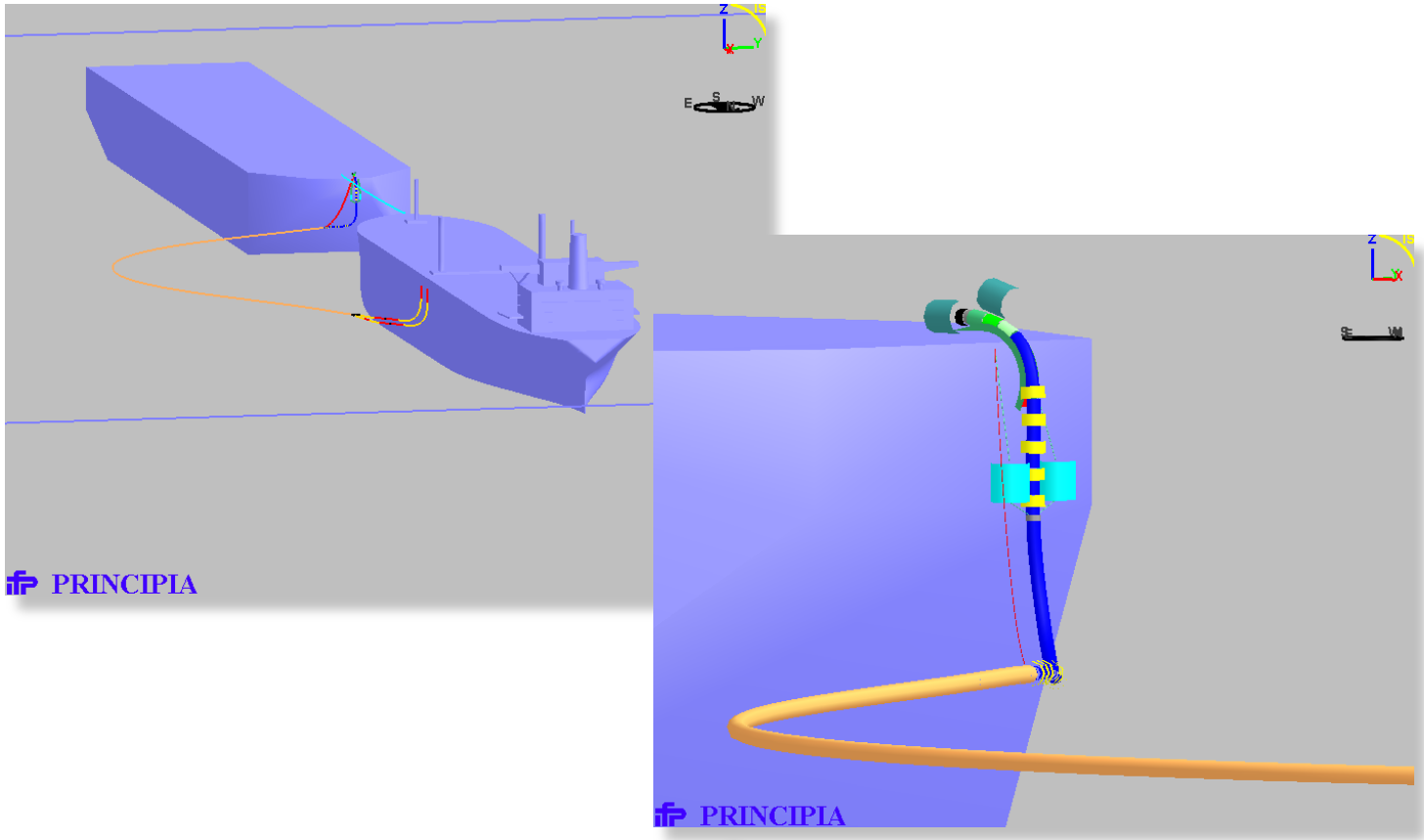
## Float-over deck installation





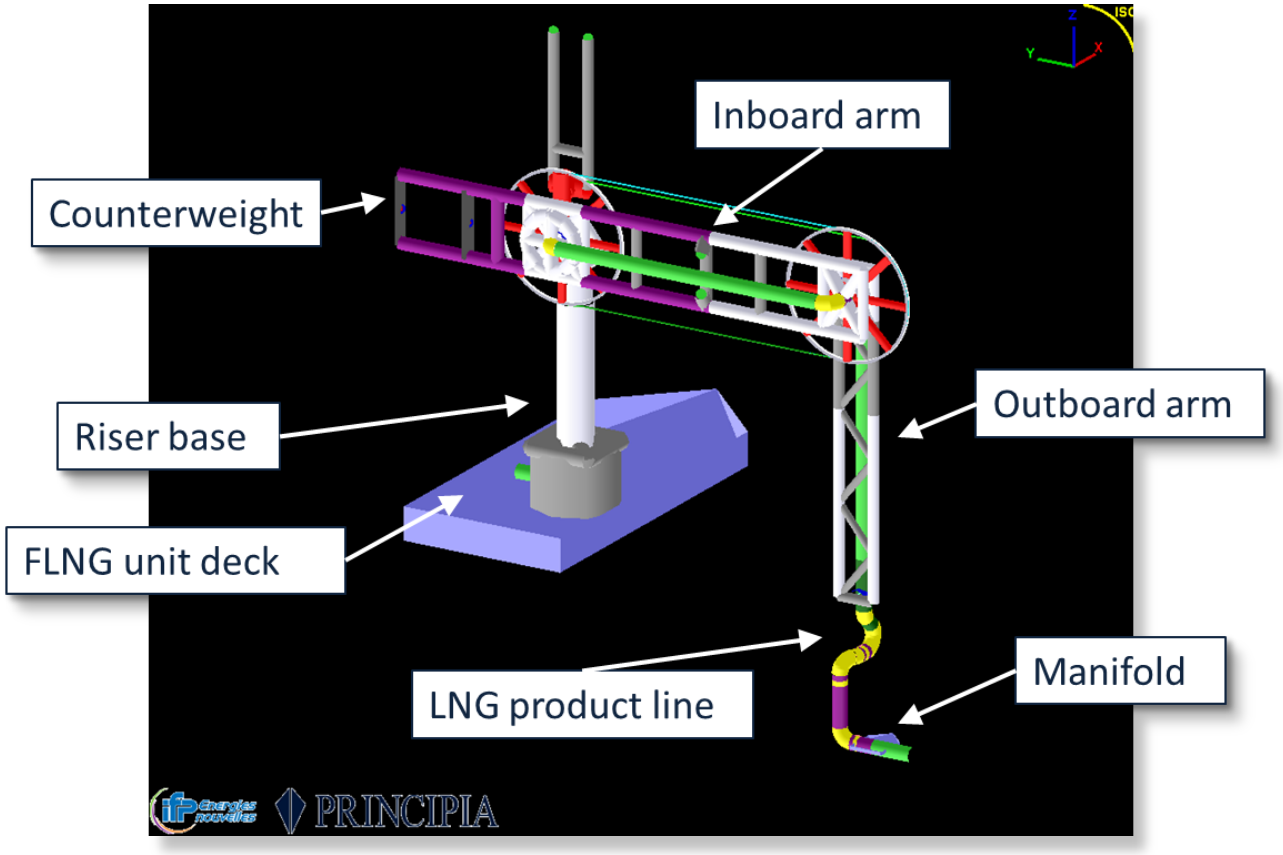
# Marine operations **applications**

## Tandem offloading with floating hoses



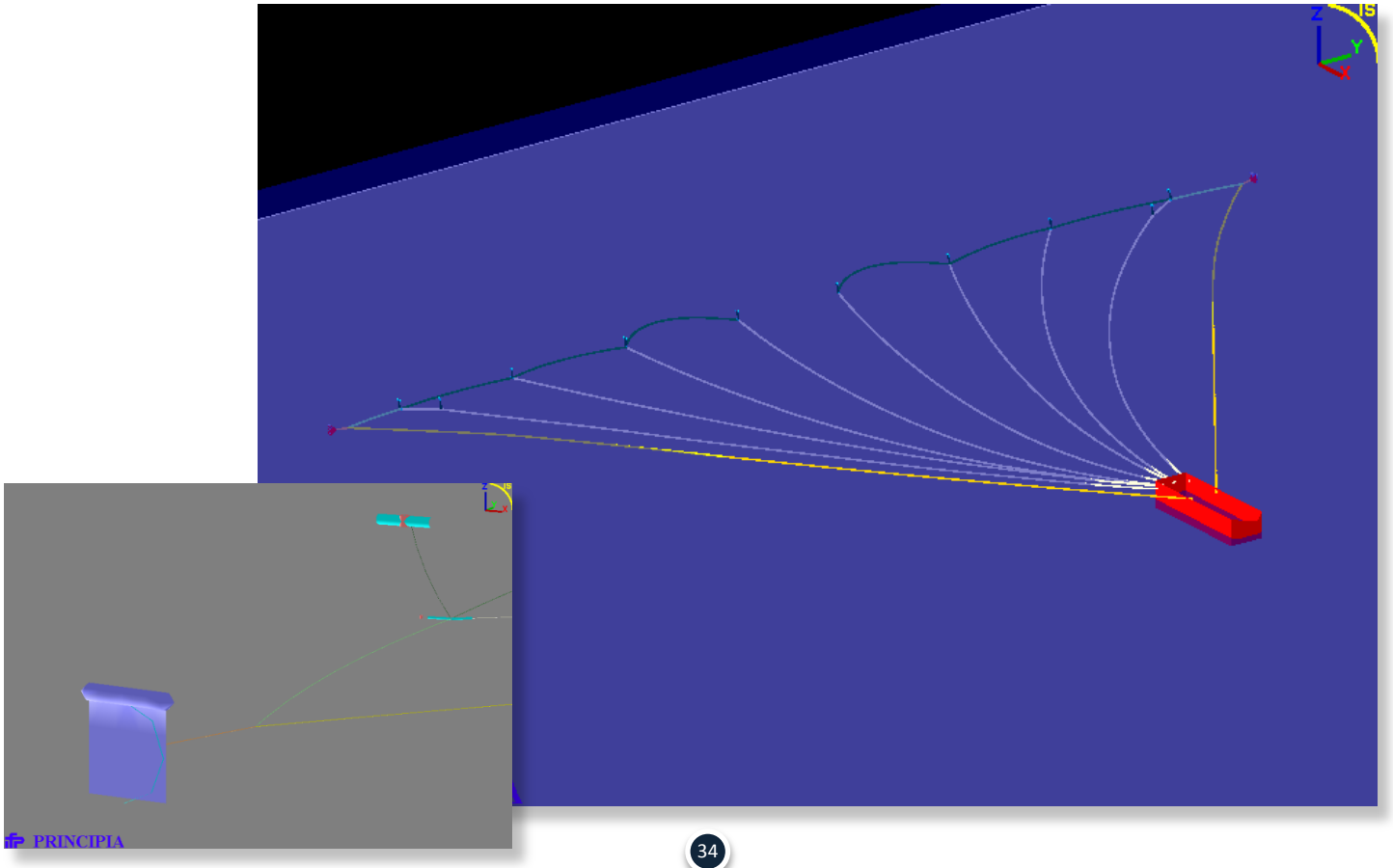
# Marine operations **applications**

**LNG marine loading arm**



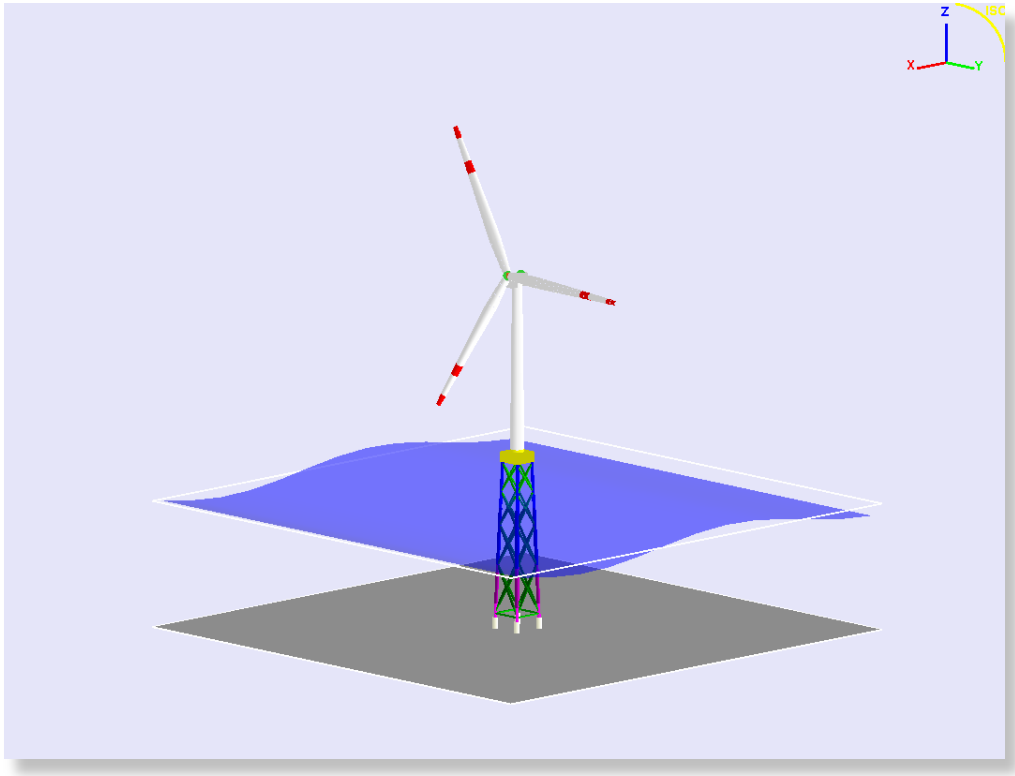
# Towed systems **applications**

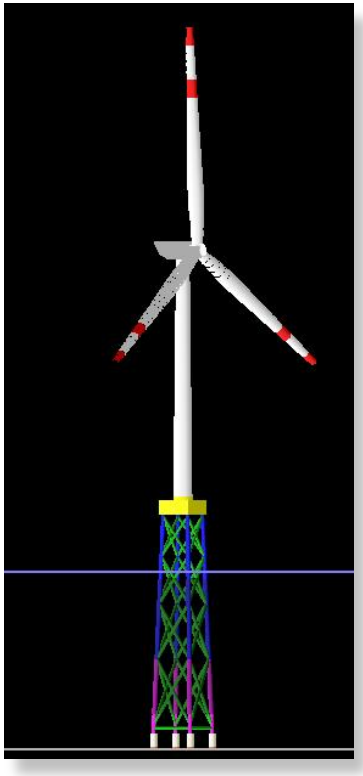
## Towed seismic streamer array



# Renewable energy **applications**

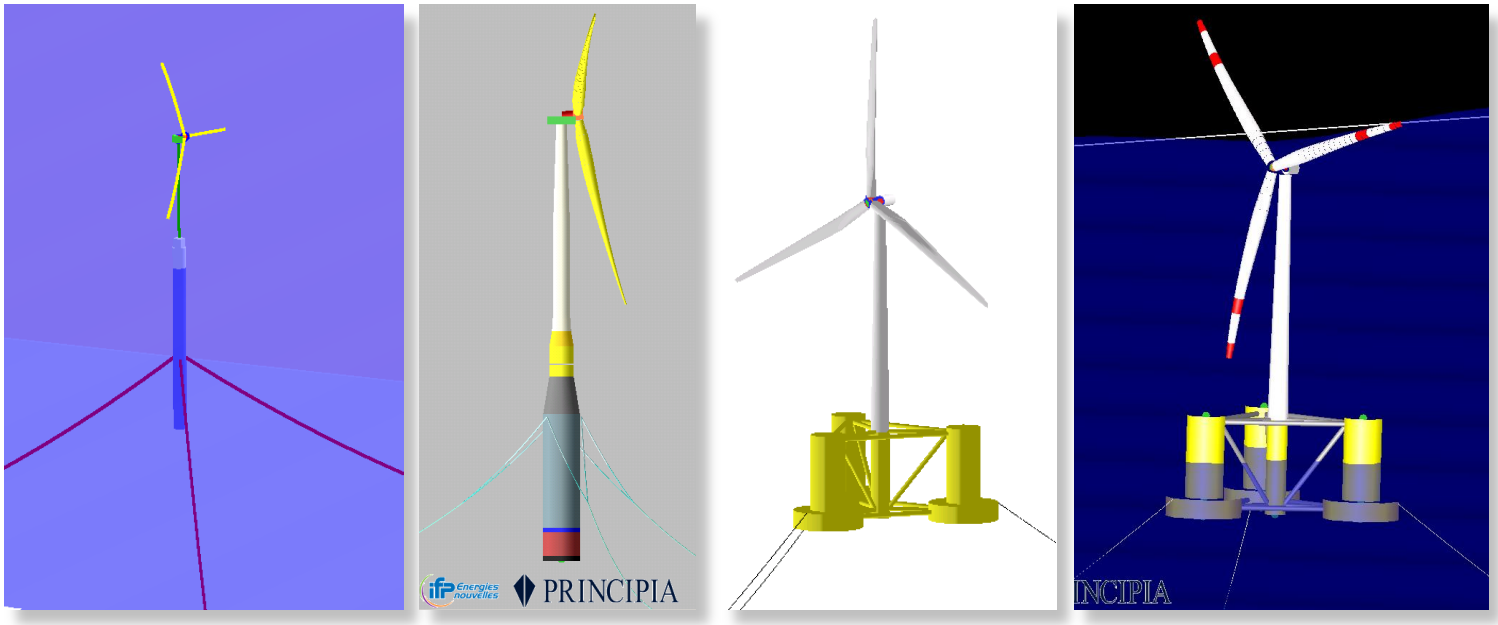
## Bottom-fixed offshore wind turbine



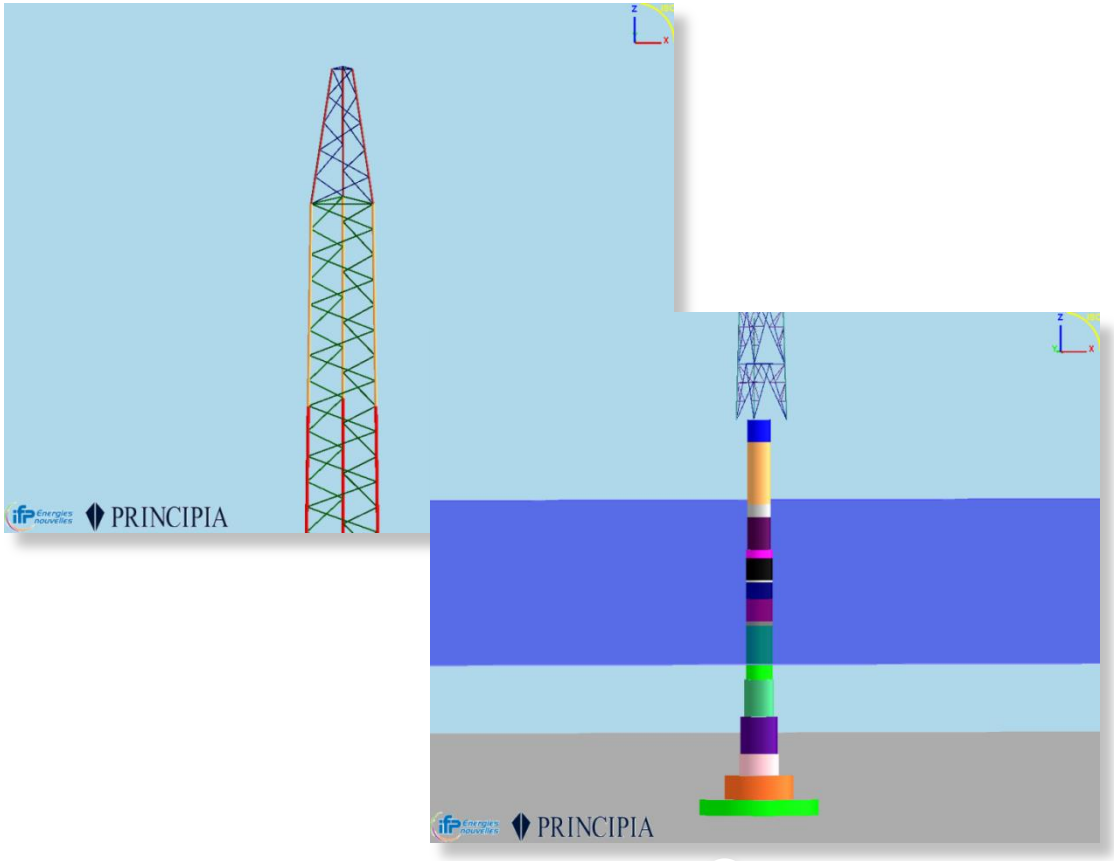
# Renewable energy **applications**

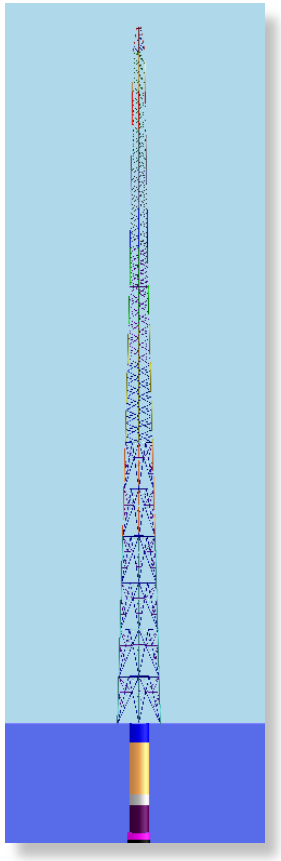
## Floating offshore wind turbine



# Renewable energy **applications**

## Met-mast

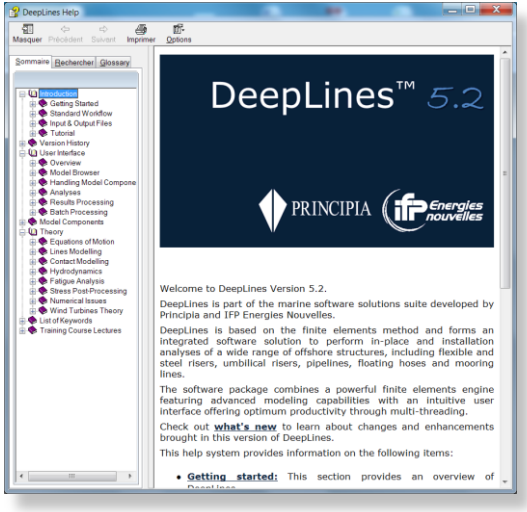


# Documents & **validation**

## Software documentation

- Complete context sensitive help system detailing the use of the GUI, data entry for every model components and all FE engine keywords
- Theory manual including both general theoretical aspects and aerodynamic loads calculation theory
- Software testing and validation report
- Training courses lectures including over 500 slides designed for self-training to complement the software documentation
- Over 50 sample models ready for use and which cover key applications
- Examples manual discussing on how to build your very first  models
- Conference papers available upon request
- Installation instructions & release notes




## Validation

The software is continuously validated through:

- In-situ data (e.g. Girassol CALM buoy), model tests and data from JIPs (e.g. STRIDE, HCR Bechtel, CALM Buoy)
- Automated non-regression tests are performed with each new version
- Comparison with other software

The software was certified by Bureau Veritas in 2000 based on comparison of software outputs with general theoretical solutions for beams  & cables and comparison with in-situ data and full scale model test (flexible risers). All certification cases are included in the software testing procedure since that time to ensure no regression.


BUREAU VERITAS
OCEAN ENGINEERING DEPARTMENT
CERTIFICATE OF DEEPLINES (VERSION 2.1) SOFTWARE
ATA 491 A 03-001

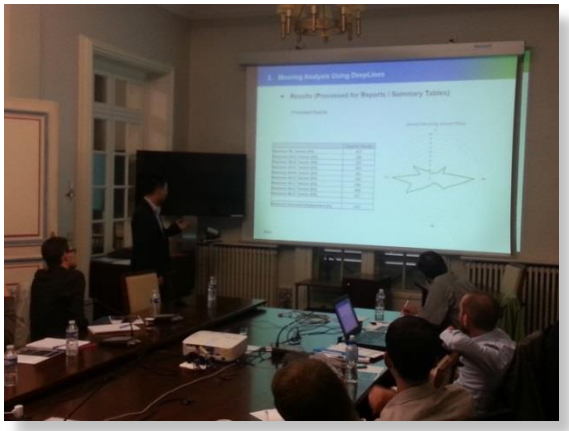
# **Training** & support

## Training courses

Principia deliver both in-company courses and public courses open to multiple companies. In-company courses may be scheduled at your convenience and run at your business premises or at a local venue if you prefer it off-site. Open courses are regularly scheduled at our facilities and announced on our website.

Our software training courses include the following:

- Fundamentals of DeepLines software (3 days)
- Coupled analysis of moored systems (2 days)
- Pipelines analysis with DeepLines (2 days)
- VIV analysis with DeepLines (1 day)
- Wave fatigue analysis in DeepLines (1 day)
- Drilling riser analysis with DeepLines (1 day)
- Offshore wind turbines analysis with DeepLines (2 days)



## Technical support

Both technical software support (for problems with creating a model or performing an analysis) and systems support (for installation, licensing, and hardware-related problems) are offered through email at deeplines@principia.fr.

## Remote installation services

Remote installation services may be provided to support your IT when deploying the software and fix any possible network license issues.

## User Group Meetings

User group meetings are scheduled each time a new major version is released, typically once a year. These user group meetings are an opportunity to learn about the most recent features included in the software, meet with the software developers and share your experience with other users. Attendance to the User Group Meetings is not restricted to licensed users.

## Free evaluation version

Temporary licenses required for potential users to evaluate the software can be issued for free upon request. The validity of these licenses is generally 1 month.

# Key **customers**




























# Licensing options

## One-time purchase

The software is available for perpetual purchase. The price for perpetual purchase includes maintenance, upgrade and support (MUS) services for a duration of 12 months. MUS services fees apply for the following years.

## Long-term rental

The software is available for long-term rental. The duration of long-term rental is 12 months. The price for long-term rental includes maintenance, upgrade and support (MUS) services.

## Short-term rental

The software is available for short-term rental with a minimum duration of 1 month. The price for short-term rental includes maintenance, upgrade and support (MUS) services.

## Lease-to-purchase option

You can convert lease into purchase at any time over the rental period. A significant proportion of the rental fees can be reimbursed upon conversion to purchase.

## Multi-copy discount

We offer multi-copy discounts on DeepLines licenses. These discounts apply to multiple licenses orders made for use by the same organization at the same site.

## Software modules

The following modules are available:

- DeepLines Base: includes all software modelling capabilities except the Offshore Wind Turbines features.
- DeepLines Wind: includes Offshore Wind Turbine modelling and analysis features in addition to the DeepLines Base module.

## Network and node-locked licenses

Network licenses let any user connected to your local area network access the software. DeepLines network licensing uses the FlexNet network license manager from Flexera Software to control a DeepLines license server. Node-locked licenses can also be provided at a reduced rate against network licenses.

## License borrowing

To provide license mobility, DeepLines supports FlexNet license borrowing. This capability lets you use DeepLines on computers that do not have a continuous connection to the license server.

## Academic licenses

Academic pricing is available for educational use at accredited academic institutions only.

# HPC on-demand services

Principia may provide High Performance Computation services to any licensed customer along with our partner Bull Atos. This brings the power of super-computers to your home and help you expedite your analyses.

## HPC services description

HPC on-demand services are based on our Linux-compatible DeepLines software version. The services that we provide include expertise on your models, running a complete set of predefined simulations using Bull Atos hardware and processing all the outputs required from the simulations. Simulation outputs are finally stored on a hard-drive and delivered at your business premises.

Batch analyses and post-processing tasks are performed by Principia experts.

## Benefits

- Get expert advice on your models to ensure convergence of your simulations and optimize the runtime
- Dramatically shorten the analysis cycle
- External storage of all your analysis files for a predetermined term
- No need to purchase and maintain in-house calculation clusters
- Brings CPU power required to optimize the design of your offshore structures

## Capabilities

Bull Atos may provide access up to 576 logic processors and 40 Terabytes storage capacity over the desired period.

| Cores # | Duration | CPU hours |
|---|---|---|
| 144 | 1 week | > 24,000 hrs |
| 288 | 1 week | > 48,000 hrs |
| 576 | 1 week | > 96,000 hrs |
| 576 | 2 weeks | > 193,000 hrs |

## “Numerical Simulation Trophies“ award

Principia’s approach towards HPC has been acknowledged by the first edition of the “Numerical Simulation Trophies”, created by Teratec with the French magazines L’Usine Nouvelle and L’Usine Digitale. During the award ceremony on June 24, 2015, at Ecole Polytechnique, Principia received the “SME Award for Numerical Simulation.”

# Local **agents**

**South Korea**

**Balance Marinetek Inc. (BMI)**
Suite 1506, Centum Green Tower.,
78, Centum Jungang-ro, Haeundae-gu
Busan, 612-020 Rep. of Korea
W: www.bmigroup.co.kr
E: deeplines-contact@bmigroup.co.kr

BMI is an independent offshore and marine engineering consultancy organization, providing high quality services to the offshore oil & gas and renewable energy industries.

**Italy**

**Oceanira s.r.l.**
Via Ilva 2/9
16128 Genova, Italy
W: www.oceanira.com
E: deeplines-contact@oceanira.com

Oceanira is a highly specialized company providing design and technical consultancy services in the oil & gas, naval, shipping, transportation and energy sectors

**Vietnam**

**Petropartner Partnership Company Ltd.**
Suite 141, 14th Floor, Ree Tower
9 Doan Van Bo Street, Ward 12, District 4,
Hochiminh City, Vietnam
E: hanhph@petropartner.vn

Petropartner is a leading oil and gas service company operating in Vietnam. Products and services range from upstream such as seismic to drilling.

**China**

**Beijing Deding Jijie Technology Co. Ltd.**
Room 612/C, Caizhi Guoji Building, No.18,
East Zhongguancun Road, Haidian District,
Beijing 100083
W: www.ddjjchina-bj.com
E: yilibin@vip.sina.com

Beijing Dedingjijie Technology Co. Ltd. is a high-tech company focusing on exploration and development of oil and gas with purpose of serving clients. The company is engaged in the exploration and development of oil, software research and development, sales, technical support and service

# About us

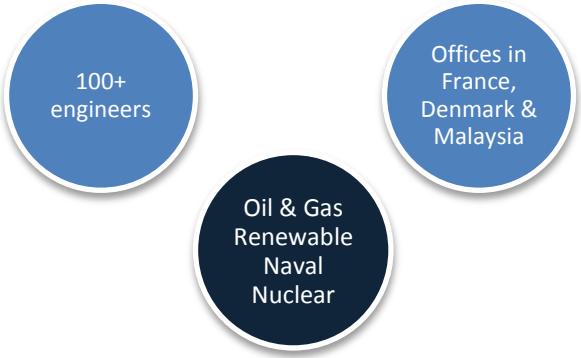
## Principia

Principia is an independent engineering, consultancy and software development company active in the fields of energy, oil & gas, naval and offshore renewables.

Our track record covers projects from equatorial swamps to polar deepwater, from oil production facilities to LNG developments.

We deliver expertise and ground-breaking engineering design services applied to floating facilities, subsea modules, umbilicals, risers and flowlines, fixed platforms, offshore service vessels and LNG terminals.

With a workforce of over 100 engineers and offices in France, Malaysia and Denmark , we can provide expertise and engineering services worldwide.

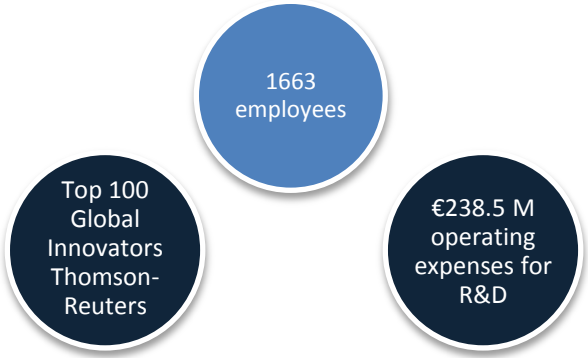



## IFP Energies nouvelles

IFP Energies nouvelles (IFPEN) is a public-sector research and training center. It has an international scope, covering the fields of energy, transport and the environment.

From research to industry, technological innovation is central to all its activities.

As part of the public-interest mission with which it has been tasked by the public authorities, IFPEN focuses on providing solutions to take up the challenges facing society in terms of energy and the climate, promoting the emergence of a sustainable energy mix, and creating wealth and jobs by supporting French and European economic activity, and the competitiveness of related industrial sectors.




www.principia.fr
deeplines@principia.fr

**France (Head Office)**
PRINCIPIA SAS
Zone Athelia 1
215 voie Ariane
13705 La Ciotat Cedex
Tel. +33 4 2 981 180
Fax. +33 442 981 189

**France**
PRINCIPIA SAS
Technocampus Océan
5 rue de L'Halbrane
44340 Bouguenais
Tel.+33 2 40 14 50 14
Fax. +33 240 143 400

**Denmark**
PRINCIPIA North A/S
Gronlandsvej 10
DK-5700 Svendborg
Denmark
Tel. +45 72 301 855

**Malaysia**
PRINCIPIA ASIA Sdn Bhd
Level 32
Menara Binjai No. 2 Jalan Binjai
50450 Kuala Lumpur, Malaysia
Tel. +60 321 660 400